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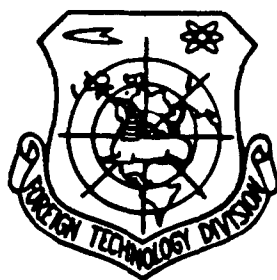


## FOREIGN TECHNOLOGY DIVISION



INTERNATIONAL AVIATION

(Selected Articles)



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#### GRAPHICS DISCLAIMER

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## CHINA'S DEVELOPING FLIGHT TEST RESEARCH CENTER

Ge Ping and Yan Jinglin

Established in April 1959, the China Flight Test Research Center (CFTRC) is the only organization in China specialized in the national evaluation flight tests and research flight tests of aircraft, aeroengines and main airborne equipments. For thirty years, it has accomplished the national evaluation flight tests of more than 10 types of aircraft and aeroengines and evaluation flight tests of several hundreds of systems and products related to avionics, instruments, high altitude escape and fire control, and has performed more than 2000 items of research and development. By 1987, the CFTRC won 3 items of the national invention prize, 30 items of award from the State, 97 items of award from the Ministry of Aero-Space Industry and 6 items of award from the Shanxi Province. Recently, it has completed the qualifying evaluation flight tests of three new types of aircraft [English Abstract].

On the dry Weibei plains of the Yellow River valley, there is a little-known aerospace industrial district. Only since China's opening up to foreign countries has its mysterious face gradually been revealed. This is the "Airplane City" in the northern suburbs of Xian. The China Flight Test Research Center (CFTRC) is one of the major features of this district.

The CFTRC was established in April of 1959. Its primary mission is to perform evaluation flight testing and research flight testing on new model aerospace technical equipment. It is China's only organization which specializes in qualifying evaluation flight testing of aircraft, engines and major airborne equipment. In the past 30 years, it has performed national qualifying evaluation tests more than ten different models of aircraft and engines. It has evaluated several hundred products and systems in the areas of electronics, special design equipment, and high-altitude escape and fire control systems, completing more than 2000 scientific research projects. As of 1987, the CFTRC had been awarded three national awards for inventions, 30 other national level awards, 97 awards from the Aerospace Industry Ministry, and six awards from Shanxi province. In the past few years, it has completed qualifying evaluation flight testing for three new model aircraft, writing a glorious page in the history of flight testing in China.

Through thirty years of hard work, this previously barren loess city has become a jewel of China's northwest, with good transportation, advanced communications, many foreign guests and throngs of businessmen and tourists.

## GENERAL DESCRIPTION

The CFTRC currently employs about 2000 engineers and technicians, including nearly 300 high-level engineers and technical personnel. It also has a corps of highly trained, experienced, and highly motivated flight personnel represented by heroes such as Wang Ang, Hua Jun and Huang Bingxin.

There are currently several dozen test aircraft at the CFTRC. These include various types and models of domestically manufactured aircraft. More than ten laboratories are separately responsible for research projects in such specialties as aircraft, helicopters, flight simulation, automatic control and guidance, free-flight models, aircraft strength, engines, powerplants, electronics, equipment, fire control instruments, and high-altitude safety and ejection. Test system research personnel are responsible for the use of airborne and surface instruments and equipment, and for the associated data processing. Equipment and test system research personnel perform research and development for non-standard equipment, test instruments and sensors especially required by the CFTRC. The CFTRC measurement laboratory ensures the accurate transfer of measurements at each test stage. There are two 3400-meter runways which are equipped with the necessary navigational equipment, including night navigation equipment. The flight base provides support for carrying out the test flights and for maintenance, and its refitting shop is responsible for making modifications on test flight aircraft.

## DEVELOPMENT OF FLIGHT TESTING TECHNOLOGY

The CFTRC special operations corps has basically matured along with China's young aerospace industry. Although it had a late start, through perseverance and hard work it has made noteworthy advances. In order to acquire all requisite specialties and overall test flight technical capabilities, the CFTRC has placed long-term emphasis on test flight methods, including special test flights. It is currently not only capable of performing qualifying evaluation flight testing for a number of different new aircraft, advanced modified aircraft and different types of systems, but it has also made some advanced breakthroughs in international advanced testing technology and theoretical methods. In several areas, it has already reached international advanced levels. For example, in its research in using parameter recognition technology to obtain aircraft aerodynamic derivatives and using Kalman filtering methods to obtain aerodynamic derivatives for helicopters, it has made contributions with practical applications. Flutter experiments, vibration measurements, and dynamic test flight methods have all been used in evaluation and research flight testing. Research has been successfully conducted in in-flight aircraft distortion

measurement and in aircraft fatigue evaluation. The CFTRC has completed research in using interior measurements, the fixed measurement rake method, and the oscillating rake method for propulsion testing, thus solving the problems of in-flight testing of engine propulsion, tension and aircraft polar curve. It has conducted experimental research on in-flight restarting and in operational stability. In the area of engine environmental research, it has found solutions for experimental methods and measurement technology involving icing, bird and gas ingestion and choking. It has also provided good technology for the in-flight testing of oscillation, temperature and strain in high-revolution engine parts. In aerospace life support systems, it has gradually evolved from engineering research toward a new stage combining engineering research with aerospace physiology. In the drafting of test flight plans, it uses system engineering for comprehensive management, resulting in substantial economic savings.

Advances in flight testing technology play an important role in major technological breakthroughs and in tackling key problems in preliminary research. The large amounts of valuable data which the CFTRC has gained through flight testing has laid a sound foundation for determining the various technical criteria required by China's aircraft design. For example, in the process of determining flight quality criteria, aircraft flight performance criteria, strength criteria, vibration criteria, engine testing criteria, instrument static norm criteria, and a whole series of flight testing standards, the CFTRC provided large amounts of reliable flight testing data. At the same time, in line with the advances in space technology, it has completed flight experiments in weightlessness.

#### DEVELOPMENTS IN TEST EQUIPMENT

Breakthroughs and developments in flight testing are interconnected with the establishment of testing facilities and testing methods and the development of testing technology.

The engine flight testing platform was the first large-scale flight testing platform built by the CFTRC which was capable of performing in-flight testing on engines. It is especially useful for debugging test flights for new model engines and research on dangerous flight test objects, as well as for various special projects. The special design electronics aircraft, made by modifying the imported jiangzhuang [transliteration] II, is equipped with a composite aerial testing control system with inertial control and radio navigation calibration equipment, and can conduct various types of missions for navigation and electronics equipment as well as for calibration testing and aerial measurements. The ejection seat test mechanism, modified and designed at the CFTRC, can perform not only in-flight

ejection, but also zero-altitude low-speed ejection on the runway. The newly developed high-speed ejection test mechanism and the variable stability aircraft will soon be put in use.

The ground testing facilities include chiefly the flight simulator, the aircraft control systems testing platform, the underground and open-air engine testing platforms, the testing platform for engine fuel and oil regulating systems, the aircraft propulsion testing platform, the ejection seat testing platform, the high-altitude test chamber, the high-voltage static electricity laboratory, and the antenna testing field. These installations have played a very major role in completing qualifying evaluation flight testing, developing preliminary research, improving flight testing methods, and in raising the level of flight testing efficiency.

In the early days following the establishment of the CFTRC, the basic airborne testing instruments were automatic recorders and optical oscillographs. In the 1960s, we developed and designed our own first-generation adjustable-frequency and digital type tape recording system, and gradually equipped domestically manufactured radio remote controlled systems for real-time monitoring of a few parameters. In the late 1970s, we successfully developed the second generation digital tape recording system and imported a data collection system and surface data processing station from France. In the early 1980s, the CFTRC imported a Lishan [transliteration] real-time data system which was a combination of magnetic tape and telemetry systems, with an emphasis on telemetry. This was an advanced system for the time, and accelerated the pace of research which was being conducted. It provided feasible testing methods for velocity parameters with strict time requirements, such as the engine intake surface pressure field distribution. In the mid-1980s, in order to have additional capabilities for the final processing of flight testing data, we imported the Qinchuan [transliteration] system, which is centered around a computer, and began to build a multiple-function remote control station. The use of these advanced level testing systems not only improved the effectiveness of flight testing, allowing a single composite test flight for modifications, during which data on a number of special items could be collected, but also provided high-quality and safe command control. This greatly increased the safety and success rate of flight testing. In addition, it also created extremely beneficial conditions for reforming flight test organization and management methods.

#### DEVELOPMENT OF COMMERCIAL AND CIVILIAN USES

In the past ten years of reforms, following the policy of development in the aerospace industry, the CFTRC has proposed the slogan "with flight testing as our principal effort, let us



engage in business, stress basic research, develop promising trends, do better in every way, and increase our prestige world-wide." The CFTRC has established a civilian aircraft testing lab which, after completing the "three continuous take-offs" project for the domestically produced Y-8 aircraft, undertook civilian aircraft airworthiness flight testing. It performed research in comprehensive and thorough flight testing methods and measurement techniques in accordance with airworthiness regulations. As China's civilian aircraft industry develops, we are confident that civilian aircraft flight testing will also become one of the major missions of the CFTRC.

In addition to conducting debugging, research and model determination in-flight and surface testing of aircraft, engines, and on-board equipment, the CFTRC also is actively preparing aerial remote measurement, remote sensing and photographic missions for the ministries of energy resources, communications, urban construction, geology, agriculture and forestry, and planning. It has undertaken development of automatic monitor and control systems and various series of remote sensors, converters and digital recording systems. It has conducted antenna design, research and development, performance testing and flight testing. It has undertaken monitoring and testing of structural strength, vibration, and noise; elimination of vibration and noise damping in airborne equipment; the design, manufacture and production of non-standard equipment for various systems; and the repair, inspection and installation of many kinds of mechanical equipment. The CFTRC has also taken significant steps toward finding products to support the civilian sector and in the production of products for export. At the present time, the CFTRC is being reorganized to adapt to developmental trends.

#### CONTINUOUS EXPANSION OF INTERNATIONAL COOPERATION

In recent years, the CFTRC has made some major advances in international cooperation. Since China's opening up to foreign nations, the CFTRC has imported much advanced technical equipment and sent more than 200 students, apprentices, visiting scholars and engineers and technicians abroad to work, study, make tours of inspection, and engage in technical exchanges, as well as develop a close relationship with their fellow technicians abroad. In the past ten years, the CFTRC has received more than 30 delegations and several hundred persons on visits of inspection and cooperation from more than ten countries including England, the United States, France, West Germany, Sweden, and Pakistan. It has also cooperated with the space research institutes of West Germany and Sweden in scientific research in such areas as flight dynamics and aerodynamics with outstanding results.

## FACING FUTURE CHALLENGES

Facing new trends of the future, all employees of the CFTRC are fully aware of the great challenges they face. Around the year 2000, there will be major breakthroughs in new aircraft development in China, and greater amounts of new technology and new systems will be used on the new aircraft, resulting in a stronger emphasis on research flight testing. From this we draw the following conclusions:

- 1) There will be a tremendous increase in the number of parameters that must be measured in flight testing. According to statistics, more than 200 parameters were tested in the 1960s; by the end of the 1980s, this figure will reach 1000. In the 1960s, 300 parameters were tested for civilian aircraft, and by the 1980s the number was about 3000.
- 2) There will be great increases in the number of test flight hours. In the 1960s, flight testing of a new model required about 700 to 1000 hours. In the 1980s, this had increased to 3000 hours. Any delay could quite possibly mean that the aircraft technology would no longer be state of the art, and that an opportunity to compete in the market place would be lost.
- 3) There will be tremendous increases in the cost of flight testing. Using foreign military flight testing as an example, the average cost for each test of one parameter is now as high as 4,400 American dollars.
- 4) There will be much greater safety problems. This will be the inevitable result of using large amounts of new technology and of an increase in unknown factors.

Facing these new trends, the CFTRC is paying close attention to developments in the advanced nations and striving to absorb advanced technology and experience. At the same time, it is interpreting its observations in light of the situation in China, in order to take steps in a number of areas to develop flight testing technology, improve flight testing performance, and reduce the cost of flight testing to business. Examples of these efforts include improving the capabilities of surface simulation testing, development of different types of testing and research aircraft, active development of testing technology and application software, use of remote control and telemetric technology and methods for determining a position in space, improving live-time monitoring and control capabilities, improving the proficiency of data processing, improving the organization and management of flight testing, and setting up a high-quality system for safety support. In its progress, the CFTRC is bringing a brand-new look to China's aerospace industry as we meet the challenge of the technological revolution in modern aerospace.

## TECHNOLOGY FOR FLIGHT TESTING OF PERFORMANCE AND QUALITY

Li Shuyou

This paragraph shows the progress of the basic performance flight test, the parameter identification, the stall/spin flight test, etc. [English Abstract]

For more than twenty years, the CFTRC, as the only flight testing center in China, has flight tested and performed qualifying evaluation testing for basic flight performance and flight quality of basic trainer aircraft, turboprop transports, heavy bombers, turbofan transports, experimental aircraft with ejector seats, variable stability aircraft, and helicopters. It has combined a number of flight testing methods and compiled an aircraft flight testing handbook suitable for use in China. It is currently beginning testing of a new aircraft with a redundant flight control stabilization system. It is also carrying out research into the interrelationships between parameter recognition and aerodynamic forces, air speed system location selection, angle of attack sensor flight calibration and angle of attack parameter recognition, the aerodynamic effects of wing-tip fins, polar curve flight test measurement, and determination of stall/superstall/spin characteristics. We will touch briefly on some of this research in this article.

### BASIC PERFORMANCE FLIGHT TESTING

In the early 1960s, the CFTRC began thorough flight testing of basic training aircraft. It is now familiar with flight testing techniques for various types of aircraft. It is capable of using different flight testing methods on different types of aircraft; examples include the loop flight method, photographic method, and radar method for measuring the airspeed system; use of the acceleration method, rotational speed method, spiraling method, differential adjustment method, and equal altitude method to determine maximum level flight speed; use of the acceleration method, zigzag method, and direct climb method to determine the climb characteristics; use of the composite characteristics graph method and elevation selection method to determine cruise flight times; use of the single item and collective indexes to evaluate maneuverability; and use of the differential adjustment method and photographic method to determine take-off and landing characteristics. In its research it has on the one hand drawn on the advanced state of science in foreign countries; it is currently studying the dynamic testing technology and the energy method used abroad for in-flight determination of performance for conventional aircraft. On the other hand, the CFTRC has also combined this with some of our own unique experience and methods.

For example, the turboprop aircraft flight testing data normally is converted to standard conditions by using the differential adjustment method. However, our experience has shown that if turbo-prop engine characteristics are used to draw up an analog graph and this graph is used as basis for conversion to an analog graph for aircraft power characteristics, the conversion is easier and more practical. Although dynamic testing technology, the energy method and the single item capability flight testing method can quickly and accurately determine overall aircraft performance indexes, it is difficult to distinguish the contribution of the various factors to performance. Therefore, we are beginning to look into a number of special methods such as in-flight measurement of aircraft propulsion and using non-fixed normal flight measurement of the lift/drag factor.

In flight testing for basic flight characteristics, if an accurate graph of the aircraft lift-drag characteristics can be obtained, a large number of take-offs and landings can be spared, reducing costs and shortening the length of the testing period. At the present time, methods for testing lift characteristics are fairly well developed, while it is relatively more difficult to measure the drag; drag measurement is also a focus of study in foreign countries. In addition to using the measurement of propulsion to determine aircraft lift and drag characteristics, the CFTRC is also studying a method that does not use direct measurement of propulsion to determine lift and drag characteristics and has had some preliminary success. This method first of all uses parameter recognition methods to determine the lift/drag factor; that is, it first establishes a corresponding mathematical model, selects a suitable form for operational input so that the measured aircraft transitional process includes sufficient amounts of the data information to be measured, and then uses the maximum likelihood method to conduct parameter recognition. The zero lift/drag coefficient is recalculated after a certain mathematical model is established, using data measured from stable-state and quasi-stable-state flight.

#### FLIGHT TESTING FLIGHT QUALITY AND OPERATING STABILITY CHARACTERISTICS

For a long time, China's flight quality flight testing has primarily been conducted according to certain foreign criteria. It was not until the early 1980s that China published a preliminary draft of its own flight quality criteria. The primary basis for these criteria was the CFTRC's accumulated materials and experience from over 20 years. Many researchers at the CFTRC made important and positive contributions in developing, compiling and testing these criteria. Furthermore, the fact that China can use her own set of criteria for flight

quality in military aircraft to undertake model design and flight testing indicates that China's aircraft design has reached a new milestone.

Verification and flight testing of operational stability characteristics has always been one of the major tasks of the CFTRC because it has a direct bearing on how to make the best use of the tactical and technical characteristics of any given aircraft. The CFTRC is currently not only capable of relatively satisfactory measurement of a great number of parameters involving basic operating control stability factors, but is currently switching over from direct measurement methods to more accurate, more effective, and more rapid indirect methods of determining the flight quality of an aircraft through the calculations of aerodynamic derivatives obtained from flight testing.

#### PARAMETER RECOGNITION TECHNOLOGY

Since the early 1960s, the CFTRC has studied and practiced using the approximation formula method, integral method, methodology function method, frequency characteristics method, simulation method, and time-loss method. It has successfully used the frequency characteristics method and the time-loss method to determine the vertical tail dimensions of a certain model of domestically manufactured aircraft. Later, as the equipment at the CFTRC was improved and became more complete, research methods gradually expanded to non-linear areas. Since the 1980s, in flight testing of new aircraft and test flights for the research of aerodynamic correlations, it has adopted from abroad the Newton-Raphson [transliteration] method and the maximum likelihood method, obtaining very good results in the extraction of aerodynamic derivatives. The CFTRC has achieved certain advances in handling non-linear problems and automatic enhanced stability system problems. Due to the increased complexity in input design of parameter recognition flight testing compared to ordinary forms of dynamic response flight testing, the CFTRC has continued to make it one of the focal points of its research. At the present time, based on the different flight testing topics and desired results, the input forms commonly used are pulse, step, double pulse, double step, and multiple step (such as 3211). In addition, the selection of measurement value weighting and the estimation of initial values of unknown parameters are also major problems for parameter recognition. Currently, some countries are using two forms: Constant weighting and weighting functions. The CFTRC has learned from practice that the weighting function method is more appropriate. Also, the proper selection of the simulation point to adjust the recursive initial value can improve the recognition accuracy, and the use of the least square method to estimate the initial values can generate all initial values. This is thus a more appropriate method.

The development of flight testing parameter recognition technology and flight performance measurement flight testing technology by the CFTRC has already made a positive contribution to the development of domestic models; these contributions include the satisfactory resolution of such problems as the azimuth static stability of the F-8 at high mach speeds and the problem of the dimensions of the vertical tail, as well as the problem of hypersensitivity of longitudinal control in the F-6. Especially during the assessment of the problem with the F-6's longitudinal control, the aircraft underwent evaluation testing at an instability of three percent. At the present time, the CFTRC is conducting research on new technology for angle of attack stability and parameter recognition.

#### STALL/SPIN TESTING

The CFTRC is using free-flight models to conduct extensive stall/spin testing for different models of aircraft, and at the same time is developing the basis for more profound theoretical research. In its stall/spin testing of such aircraft as the FT-5, F-6 and FT-6, it has obtained a great deal of valuable data. Working together with other units, it has determined a number of laws governing these characteristics and summarized the "level, neutral, yield" method of getting out of a tail spin. This has contributed to improving the level of air force training and reducing the number of accidents.

At the present time, the CFTRC is conducting stall characteristics tests on the Y-7 and is actively preparing to conduct stall/spin tests for delta-wing high-speed aircraft.

## CIVILIAN AIRCRAFT FLIGHT TESTING TECHNOLOGY

Li Ju, Chen Zhaozhuo

This paragraph introduces the progress of flight test technology in civil aircraft development [English Abstract].

Prior to the 1980s, the CFTRC had undertaken qualifying evaluation testing of Y-7 and Y-8 aircraft designs and flight capability comparison flight testing of the Y-5 before and after modifications to electronics navigation instruments. Because China did not have civilian aircraft airworthiness regulations to follow at that time, it was forced to use military aircraft flight testing methods for appraisal flight testing of these aircraft. Even so, the CFTRC made certain advances in turbo-prop engine performance conversion methods and slow-speed flight testing techniques. Not only did the CFTRC make contributions toward the qualifying evaluation for production and route application of the Y-7 and Y-8, but it also took its first welcome step on the road to flight testing of civilian aircraft.

Between 1982 and 1984, the CFTRC began using the requirements of the United States' FAA civilian aviation regulations in its flight testing for flight performance and stability characteristics of the Y-8, completing the highly difficult and dangerous flight testing items of minimum control speed check during stall, aborted take-off, continued take-off, and touch-and-go landing. This has filled in the gaps in the key engine power-loss and take-off and landing performance flight testing for China's heavy transports.

Early in 1986, the Ministry of Aviation Industries organized a crack team to determine the stall characteristics of the Y-7. The CFTRC was responsible for stall flight testing. This flight testing program required demonstration of aircraft stall speeds while cruising and during take-off and landing, the level flight speeds, turn stall speeds and the single-engine stall speeds. These were new tests and were very difficult. This flight testing is still being carried out. When it is completed, it will clear away a major obstacle to future civil aircraft airworthiness evaluation flight testing.

In 1988, the CFTRC began carrying out thorough flight testing of the Y-7. The objective of this mission was to elucidate a number of safety problems in the AN-24 which were detected in use and in powered wind tests and to recommend steps to alleviate these problems. Another objective of this mission was to provide reference data for the stall flight testing of the Y-7 and the development of a modified version. The first stage of flight testing for this plane has already been completed. The flight testing, in both flight testing methods and testing technology,

can be said to have advanced China's civilian aircraft flight testing to a new level.

As for flight testing, this was the first time flight testing was conducted according to the methods recommended in the "China Civil Aviation Regulations, Volume 25" and the United States FAA "Transport Aircraft Standards Flight Testing Guide." Static and dynamic stability flight testing was performed. It was also the first time that the towed-cone method was used to measure the positional deviation of the aircraft air-speed system (the aerodynamic adjustment value). Through this flight testing, the primary data on the longitudinal and transverse controllability and stability were obtained; they include the neutral point and the dynamic point, the rear limit of the center of gravity, the aileron performance and the affect on landing and re-take-off performance and operating stability of different flap settings. A landing and re-take-off procedure for improving re-take-off performance was proposed.

As for testing techniques, three major breakthroughs were made. Real-time on-board processing and monitoring of data were realized. A water distribution system was used to adjust the center of gravity automatically during flight. A towed cone system was used to measure the reference static pressure.

The real-time data processing and monitoring system ensures that a quick evaluation is made of how well the quality of the flight testing mode is maintained. If requirements are not met, additional flights can be made right away, reducing the number of test flight take-offs and landings and lowering the rejection rate for data.

Development of the automatic center of gravity adjusting water distribution system began in 1987 because the manual distribution system used in the past made the adjustment of the center of gravity very time-consuming and also could not ensure that the location of the center of gravity was where it was required. This system was used for the first time in the Y-7 flight testing. The center of gravity can be controlled by computer, storage calculator, by water level and manually. In case of a malfunction or an emergency, the emergency control system can bring the center of gravity from anywhere it might be at the time back to the normal location. This system can also correct for center of gravity deviation caused by fuel consumption, keeping it at one percent, within the length of the aerodynamic chord. Currently, this system can adjust the center of gravity at a rate of 1.55 percent of the aerodynamic chord per minute. Researchers are currently making further improvements to this system, in hope that the use of a microcomputer can turn it into an independent system, thus freeing the on-board computer for controlling other features or systems, and also accelerating center-of-gravity adjustments, thereby increasing flight efficiency.



The towed-cone system is a static pressure measuring system towed behind the vertical tail. During flight, this system can position the static pressure measuring tube a long way from the aircraft (up to 40 meters), basically avoiding the effects of aircraft turbulence, and obtaining more realistic environmental pressure readings than possible by locating the pressure measuring tube anywhere on the aircraft; at times, it achieves a virtual zero-level error. Therefore, the reading cannot only be used as a reference pressure for correcting the positional error of the aircraft airspeed system, but can also be used as a reference pressure for the aircraft aerodynamics and performance data. This is especially useful when putting the aircraft into a stall mode. Foreign countries began using this type of system in the 1970s. It is now being widely used for research-type flight testing and for airworthiness evaluation flight testing. However, this was the first time it was used in China for flight testing.

We have found through experience that the towed cone system not only provides accurate static pressure data, but also reduces the error and improves the accuracy of flight testing results because its deviation is not affected by the flight zone.

## THE BW-1 LONGITUDINAL VARIABLE STABILITY AIRCRAFT

Zhou Ziquan

BW-1 longitudinal variable stability aircraft is the first in-flight simulation test research aircraft in China, modified from FT-6 jet-trainer aircraft. It is equipped with an electro-hydraulic servo artificial feel system, a aerodynamic variable stability system, a simulated target motion tracking display system, a data acquisition, recording and telemetry system. Meanwhile a real-time monitoring, recording, warning and data processing system is installed on the ground station. BW-1 can be used for evaluation of mechanics and control technology, in-flight simulation of new type of aircraft, flight test pilot training and validation of ground simulation [English abstract].

The BW-1 longitudinal variable-stability aircraft is China's first in-flight simulation testing research aircraft. It is modified from the FT-6. Modification work on the BW-1 was completed in March of 1988. In October of the same year, ground testing was completed. At the present time it has entered the test flight stage. It is planned that acceptance testing will be completed in 1989.

### SYSTEM MODIFICATIONS

Extensive modifications were made to the aircraft. The forward cabin was changed to an evaluation pilot cockpit. The rear cabin was made into a fixed-state cockpit for the back-up pilot. Primary modifications on the aircraft itself included the installation of an electro-hydraulic servo artificial feel system, an aerodynamic variable stability system, a simulated target motion tracking display system, and a data acquisition, recording and telemetry system. The first two of these systems are jointly called the variable stability control system. The ground station is equipped with a real-time monitor and controls and recording, warning and data processing systems.

Among the flight controls, the forward cabin control stick was converted to electrical control while the control stick in the rear cabin remained mechanical with an electromagnetic clutch between the two. When operating with variable stability, the clutch is open. When the clutch engages, the variable stability control system is disconnected and either control stick can be used to control the aircraft. The steering controls of the aerodynamic variable stability system and the artificial feel system are connected by a hydraulic clutch and a mechanical control system. When operating with variable stability, both clutches are engaged with the mechanical control system. In the

hydraulic system, fine oil filters are installed ahead of both the steering controls. The hydraulic reservoir of the original system was replaced with a sealed hydraulic reservoir which is filled under pressure. In place of the original sighting device, a target tracking display was mounted. In all, 136 new pieces of equipment were installed in the aircraft. A compartment in the belly of the aircraft was converted expressly to accommodate the equipment. The exterior of the aircraft is shown in a special color insert [not included in translated material].

#### OPERATIONAL PRINCIPLES OF VARIABLE STABILITY

Figure 1 is a block diagram of the BW-1 systems. During variable stability flight, the evaluation pilot uses the artificial feel system to move the control stick. The control signal is sent to the simulation computer, which calculates and sends out the control stick movement signals using the artificial feel mathematical model, driving the artificial feel steering controls. The trim circuit can provide the control rod with trim movements for various speeds.

The position sensor of the artificial feel steering controls transmits the signal for a change in stick position to the digital computer. After the control stick model in the aircraft control system has been calculated, the amount of simulated rudder turn is transmitted to the aerodynamic variable stability system, thus allowing the evaluation pilot to exercise electronic control of the simulated aircraft.

The aerodynamic variable stability system has dual capability for response feedback and model following. In the model following system, the control stick model system transmits the simulated rudder surface to the mathematical model of the aircraft being simulated. The model's response output is tracked by the simulated aircraft's servo control tracking ring. Therefore, the operating response the pilot perceives is equivalent to the response characteristics of the simulated aircraft. In the response feedback system, it is only necessary to use digital computer regulating methods to match the characteristics of the simulated aircraft with the acceleration and pitch rate feedback gain.

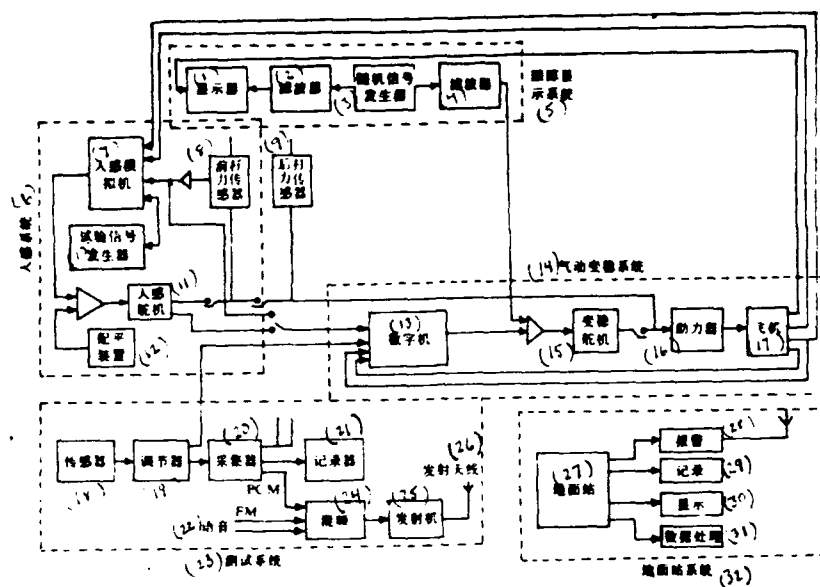


Figure 1. Block diagram of the BW-1 systems. Key: (1) Display; (2) Wave filter; (3) Random signal generator; (4) Wave filter; (5) Tracking display system; (6) Artificial feel system; (7) Artificial feel simulator; (8) Forward stick movement sensor; (9) Rear stick movement sensor; (10) Test signal generator; (11) Artificial feel steering controls; (12) Trim installation; (13) Digital computer; (14) Aerodynamic variable stability system; (15) Variable stability steering controls; (16) Booster; (17) Aircraft; (18) Sensor; (19) Regulator; (20) Accumulator; (21) Recorder; (22) Speech; (23) Measurement system; (24) Frequency mixer; (25) Transmitter; (26) Transmitter antenna; (27) Ground station; (28) Warning; (29) Recording; (30) Display; (31) Data processing; (32) Ground station system.

There are four control modes on the variable stability control panel in the rear pilot's cockpit: Response feedback, linear acceleration tracking, pitch rate tracking and manual control. There are also four sets of parameter-changing knobs and three sets of speed-adjustment knobs. In all, 256 parameter sets can be loaded in the computer. Each parameter set includes 48 variable parameters. For the convenience of pilot operation, only four sets of parameters may be altered for each mode during a flight.

The system is equipped with a standard test signal generator which can generate different test signals as a substitute for pilot controls.

The variable stability system has a fault safety pattern. The other signal source generators for the sensors and system output all use backup measures, and the important components all have automatic monitoring and control. When the aircraft's linear acceleration is restricted, the major angle of attack can sound a warning. The forward and rear pilots both have emergency disconnect buttons and switches.

Symbols for "TARGET" and "FRIENDLY AIRCRAFT" can be displayed on the target motion tracking display. The "TARGET" is driven by a signal from the random signal generator. The "FRIENDLY AIRCRAFT" is driven by a signal from the gyroscope platform. The random signal generator is composed of a white noise generator and a special wave filter. The time constant of the wave filter can be changed. The pilot can use pursuit or compensation methods to implement tracking flight.

The random signal generator can also send a signal through different wave filters to the aerodynamic stability steering controls to simulate the effect of different frequency atmospheric turbulence on the pitch movement of the aircraft.

The data accumulator, recording and telemetry systems on the BW-1 can measure 150 parameters, including both PCM and FM signals. These signals are recorded on board the aircraft, and are also sent to the surface where they are monitored by the ground station. The data accumulator has an overload alert and has the capability of automatically restricting the variable stability control system by limiting such parameters as linear acceleration, rate of pitch, pitch angle acceleration, angle of attack and control stick force. In addition to real-time display and recording of the various parameters, the ground station also has a set of real-time warning and parameter recognition systems. If aircraft or system parameters reach a predetermined hypothetical value, the ground station automatically sends a warning signal to the pilot.

## SURFACE TESTING

Surface testing includes laboratory simulation and on-board surface testing.

The primary objective of laboratory testing is to conduct system verification and testing, starting out from the general flight testing program; it includes performance testing, fault testing, and pilot control testing. The testing is conducted on the SB-6 control simulation testing platform. Results have demonstrated

that the BW-1 has excellent in-flight simulation capabilities. Four pilots (including one British test pilot) have conducted open loop and closed loop control flights on the simulation platform, including overload pursuit and maintenance, attitude pursuit and maintenance, and target pursuit. They unanimously felt that the BW-1 is very effective in the study of flight quality.

On-board overall surface testing of systems includes performance testing, electromagnetic compatibility testing and structural modality coupling testing. In comparison with the results of the laboratory testing, the artificial feel system and the system fault instantaneous mode characteristics show some improvement; most of the other results are about the same.

The structural modality coupling testing is divided into the open loop and closed loop tests. It uses a harmonic signal excitation system to measure the open loop and closed loop frequency response characteristics. It also uses a pulse excitation control stick to measure elapsed time with the loop closed. The results have demonstrated that without a structural filter, or when the wave trap point is not properly set, individual conditions do not satisfy the NYQUIST criteria. After the wave trap point has been adjusted, the system satisfies the structural modality coupling stability requirements very well.

#### THE BW-1 FLIGHT TESTING PROGRAM

The flight testing program is carried out in six steps.

The first step is surface taxiing. This is to check if the various systems are operating normally following modification.

The second step is modification flight testing. This is the flight testing of the modified aircraft with the variable stability controls not being connected to the aircraft's main control system to check that aircraft capabilities and system operation are normal.

The third step is flight testing of the artificial feel system. The aerodynamic variable stability rudder is disconnected from the main control system machinery. The rear cockpit pilot controls the aircraft. The pilot's control stick is released, and the front cockpit pilot conducts feel control with artificial feel characteristics. Other parts of the variable control system are put into operation. Initial checks are made of the operations of the electrical systems.

The fourth step is the flight testing of the quasi-closed loop system. The system is put into operation in its entirety. However, the linear acceleration sensor and the rate of pitch

gyroscope feedback gain are set at almost zero. The system is about the same as an open loop. Further testing is done on the operation of the entire system.

The fifth step is the closed loop flight testing of the variable stability control system. It is gradually expanded to the ranges of the overall design capabilities and the limits to which the parameters can be varied.

The sixth step is practical flight testing of the variable stability aircraft.

#### APPLICATIONS FOR THE BW-1

Operations in the following areas have recently been developed for the BW-1.

1. Training flight testing personnel. Using a variable stability aircraft to train test pilots is an effective means of keeping firm control of the flight quality flight testing technique and evaluation of methods.
2. Flight quality research, especially research in flight quality of aircraft with electronic controls.
3. In-flight flight simulation of new aircraft.
4. Research into control technology. The BW-1 uses digital electronic controls which can be used to conduct research into digital control technologies such as control pattern design, selection of sampling rates, software design, and insensitivity design. In addition, with slight modifications, it can also be used for lateral rod control research.
5. Verification of ground flight simulation.

## CONGRATULATIONS AND BEST WISHES!

In April of this year, the China Flight Test Research Center (CFTRC) celebrated its thirtieth anniversary.

During these thirty years of difficult pioneering work, CFTRC has completed government qualifying evaluation flight tests on more than ten types of airplanes and engines, flight test evaluations of several hundred items of aviation equipment and systems, and over two thousand scientific projects. According to 1987 statistics, CFTRC has won a total of three national invention prizes, thirty other awards at the national level, 97 ministerial-level awards, and six provincial-level awards.

CFTRC has become a 2,000-strong scientific and technological research team. Team members include nearly 300 high-level scientific and technological workers; highly trained and experienced, hard working and conscientious, and showing a bold spirit of adventure in their investigations, they have made valuable contributions in establishing China's aviation flight test research base and in developing the work of flight test research. Wang Ang, Hua Jun and Huang Bingxing -- the heroes of flight testing -- are outstanding representatives of these men.

CFTRC is China's central organization for aviation research flight testing and qualifying evaluation flight testing for technological aviation equipment. Under the new influence of the reform policies to open China, the Flight Test Center anticipates an even brighter future.

In commemoration of the 40th anniversary of the People's Republic, to publicize our success in building China's aviation industry, and to encourage international exchange in the field of aviation science and technology, our editorial staff has published this group of essays. We hope readers in China and abroad will find them interesting.

With best wishes to the China Flight Test Research Center in attracting talented workers. May success crown success!

The Editorial Staff of Guoji Hangkong



## EXPERIMENTS TO MEASURE FLIGHT TEST VIBRATION AND FLUTTER

Guan Peifang, Zhong Dejun

In the process of new aircraft development, it is necessary to accurately measure the vibration level and model and to find flutter phenomena to guarantee flying safety. The testing and measuring methods and equipment used by the Center and work done so far are described [English abstract].

### 1. The Role of Vibration and Flutter Measurement Experimentation in the Study of New Models

When an airplane starts up on the ground, takes off, lands, taxis, and flies, aerodynamic, mechanical and acoustic factors that are present from start to finish cause it to vibrate. In order to ensure that a new plane does not vibrate so much that it has a negative effect on the plane's structure, its equipment, or crew, it is necessary to undertake measurement of flight vibration. The measurement data is an important tool for determining the basis of the vibrational environment, searching out causes, and finding effective anti-vibration measures.

Flutter is a self-induced vibration produced from picking up the energy from the oncoming flow of air, linking the airplane's structure and its degree of independence. When flutter occurs during flight, there is often the possibility of serious accidents. In-flight flutter experimentation is not restricted by simplified hypotheses; it measures actual data with a real structure during real flight conditions in order to determine a new plane's resistance to flutter. This is thus a key concept in evaluation flight testing of new aircraft.

### 2. Measuring Flight Vibration

In foreign countries, the standardization of in-flight vibration measurement was achieved early. In the American military's standards relating to environmental experimentation, published in 1983, it is clearly stated that it is necessary to undertake in-flight vibration measurement to ensure the structure of the fuselage, the components, the equipment and the crew would not be affected by excessive vibration that was capable of causing structural fatigue, loss of responsiveness in equipment, and a lowering of the crew's working efficiency.

The testing system for measuring vibration is basically composed of sensors, amplifiers, recording devices and analytic devices. Currently, the Flight Test Center has at its disposal a variety

of accelerometers, on-board electrical charge amplifiers, high-pass and low-pass wave filters, magnetic tape recorders that can be used for mixed frequency recording, and many digital signal analysis systems capable of carrying out the task of data processing for environmental vibrational measurement and bombardment vibration in all kinds of aircraft, as well as for vibration-elimination test flights.

The Flight Test Center has already implemented in-flight vibrational measurement on six aircraft, including China's F-6 and B-6, investigating the vibrational environment of these planes in order to provide data for the development of new planes and for establishing standards for vibrational environment testing of on-board equipment. In addition, it has also performed bombardment vibration measurements on three types of aircraft, including the F-7 II, clarifying the bombardment vibration environment of these models. Most recently, it provided reference data on the vibrational and bombardment environment for the relevant locations during the course of an engineering project involving re-equipping of the fire control system in new model planes. In the area of eliminating vibration, it has undertaken anti-vibration flight testing, designed to provide data to eliminate excessive vibration, for vibration in the Fenfa [transliteration]-530 metal propeller (2.5 meters), for the supersonic longitudinal shaking and the sudden sideways slipping and nose elevation in the F-8, for vibration in the aerial test bed for the B-6's reequipped motor, for vibration in the SH-5, and for vibration in the F-8's air-speed tube.

### 3. In-Flight Flutter Experimentation

The first in-flight flutter experiment took place in 1935; critical in-flight flutter testing technology, with its large element of danger, was abandoned early, gradually developing into sub-critical flight flutter testing methods with other linked results in the field of anti-flutter study as their foundation (such as theoretical flutter analysis, small-scale flutter model wind-tunnel experiments, and surface resonance experiments), using a variety of advanced equipment and instruments and many high-speed, high-accuracy data analysis techniques. Currently, test-flight flutter experimentation abroad is considered an indispensable item in the evaluation of new aircraft, in order to guarantee that in actual limiting ranges no aerodynamic elasticity, aerodynamic servo elasticity, aerodynamic hot elasticity or other conditions leading to instability will occur.

In China, as our aviation industry moved from imitation to its own design, our derivative flutter studies also gradually evolved into a system. Test-flight flutter experiments began in the 60s, and one by one solved technological problems in the fields of the

origins of vibration, the measurement of vibration and data processing, successfully completing test-flight flutter tests on the wings of a series of F-8 structural models and their derivatives, with four guided missile models, and a series of F-7 III models.

In the area of vibration testing technology, an effort has been made to integrate China's special requirements in the study of suitable fighter plane flight vibration tests. Use was made of a small rocket as a source of pulsation vibration. These small vibration-stimulating rockets have now grown to a series; they are able to stimulate major structural components including the wings, fuselage, and horizontal and vertical tail fins. Work has also been done on using natural aerodynamic turbulence as a random vibration-stimulation technology. In addition, there are also magnetic vibration-stimulating systems that can be used in large and medium scale aircraft vibration flight testing. The use of aerodynamic vibration stimulation from attached wings (vibration or rotation wings) and operating surfaces is now under investigation. In the area of measurement technology, we have mastered the use of a whole range of measurement systems, including many kinds of accelerometers, emergency electrical bridges, on-board magnetic tape recorders, telemetric transmitters, and real-time surface monitoring equipment. Follow-on data processing methods and parameter discrimination technology are also being constantly improved. The PS600 vibration analyzer that is in use and the MITRA 125 computer are shown as Figure 6 of the center insert [not included with translated material].

It can be seen from this that the Flight Test Center not only has a mature understanding of vibration flight test technology for fighter and attack planes, but will soon develop flight test vibration experiments for large and medium-size transport planes, making a contribution to the development of new model aircraft.

## CAAC XIAN ADMINISTRATION BUREAU HAS BEEN REORGANIZED

Hu Yongyuan

Following the completion of the work of reorganizing the former CAAC Chengdu, Shanghai, and Beijing Administration Bureaus according to the reform policy of separating government and business, CAAC announced in Xian on 23 April of this year that the original Xian Administrative Bureau has been reorganized as the Northwest Administration Bureau, the Chinese Northwest Airline, and the Xiguan Airfield; in the near future, after a period of trial operation, official operations will begin.

## THIRTY YEARS OF POWERPLANT FLIGHT TEST RESEARCH

Zhu Chaodong, Shou Shengde, Qiao Wenxiao

The powerplant flight test research is one of important tasks undertaken by CFTRC. In the article the authors present the progress and scientific activities in this field during the recent 30 years [English abstract].

Test flight research for aircraft powerplants is an indispensable link in the work of developing engines. In foreign countries, the amount of time in the developmental cycle of aircraft engines represented by powerplant flight testing basically is equivalent to the total time devoted to powerplant design and development. In China, two to three years are generally required.

There are two objectives in powerplant flight test research: The first is to undertake qualifying evaluation test flights for new engines on behalf of the state and to test whether the new engine has achieved the requirements of the design specifications under conditions of actual use, as well as to test whether the design, developmental, and experimental standards are in conformity with reality. The second objective is to develop specialized test flights and pre-research test flights, in order to supply reliable data for the improvement of the new design and model. For this reason, flight test research is not only the last phase in the development of new engines, but marks the beginning of research for new engine models.

### THE MAIN TASKS AND SPECIAL FACILITIES

For the past thirty years, CFTRC has shouldered the responsibility of national qualifying evaluation test flights for all kinds of powerplants. It has also completed many investigatory flight test projects, providing a set of powerplant flight testing methods and measurement technology, as well as a full series of flying test planes and surface simulation equipment, all appropriate to China's individual conditions.

The most important of the Center's powerplant flight test research projects include:

- o Adjustment and qualifying evaluation test flights for new engines and powerplant systems;
- o experimental research on engine flight loads;
- o research test flights for a variety of engine systems and research flights for new oil products;

- o research on powerplant flight testing methodology and measurement technology;
- o special and preliminary research test flights for powerplants, and
- o ground-based simulation and environmental research for engines.

#### MAJOR SCIENTIFIC RESEARCH ACTIVITY

Over the past thirty years, the Flight Test Center's scientific research test flight activity in the area of powerplants has, broadly speaking, gone through three phases: A period of formation, a period involving principally qualifying evaluation tasks and a period of emphasis on special problems and basic research. Over twenty models of planes have been tested, and over thirty engine models have been test flown; over 300 flight testing projects have been carried out. The most significant scientific successes were achieved in the following areas:

##### 1. Special Test Flight Research on the Working of Powerplants

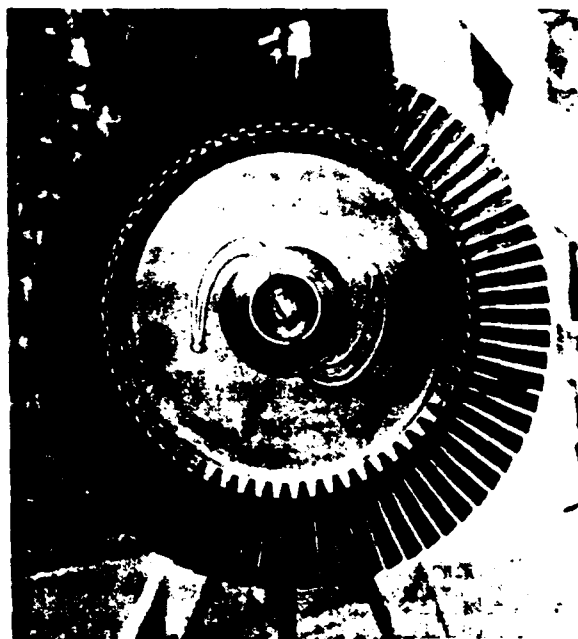
All engines, both those which China has copied and those which China has developed on its own, have all been subjected to special working test flight research, including the study of mid-air starting capabilities, special throttle acceleration research, research into engine operation during weapon launching, research on working stability of engines (gasping/shuddering characteristics), experimental studies on the working quality of the afterburner fuel chamber, icing experiments on engines and propellers, vibration experiments, the study of engine operating systems, indicator systems, automatic adjustment systems, and cooling and ventilation systems, and similar special research of a practical nature.

Of these items of research, mid-air starting and weapon launching are important topics with a relatively high level of risk. Since the 60s, we have performed many mid-air starting experiments on prototypical aircraft and flying test beds on series including turbojets and turboprops, and special test flight research on high-specific gravity fuels and fuel starting limiting conditions. In over ten projects on mid-air start-up, in addition to verifying the engine's starting limits, we undertook a wide range of research on start-up under all sorts of working conditions (such as head-on start-up, start-up at supersonic speeds, high-pressure start-up, low-speed start-up, start-up under a variety of flight attitudes, start-up with engines at various degrees of coldness, and, for twin engines, start-up with the left and right engines in different working states. From this research, we have been able to provide scientific data for

flight crews on how to manage the critical moment of start-up during flight and establish reliable starting conditions, thus ensuring safe operation; we have also furnished data for improving starting systems. Beginning in the 70s, we have been using low-inertia thermocoupling and other dynamic state sensors, as well as high-speed photometric methods to study the effects of on-board artillery and missile launching on the working of the engines, as well as the reasons behind gasping/shuddering and stalling, and have obtained much experimental data. These important research projects are currently still being pursued in greater depth.

## 2. Special Research on Engine Capabilities

Since the 60s, in measuring the in-flight net engine thrust, we have converted the in-flight experimentally measured performance to capabilities under standard atmospheric conditions, and have accurately established effective engine thrust after installation (that is, considering the loss and gain produced by the air intake and exhaust system; this is also called the installed engine performance). We have also begun much research on other key fields. We have experienced great development in the fields of thrust measurement methodology and theory.



No-load temperature measurement on a turbine element.

At the beginning of the 80s, to investigate the "external measurement method," we successfully developed the water-cooled rake. On three kinds of turbojet engines, we undertook performance characteristic test flights, and obtained relatively accurate high-speed capability readings while using full and partial afterburning under maximum states for these three kinds of engines.

The "drag measurement rake" developed for propeller engines has made possible research on drag characteristics.

In order to lay a technological foundation for the integrated design of new propulsion systems, as well as for the careful study of the interrelationship between wind tunnel and flight, we

are currently further advancing our work of studying the installed performance of engines.

### 3. Experimental Study of Flying test beds

Flying test beds are principally used in debugging test flights for new engines and for special test flights. They are a kind of transitional experimental plane. On a high-elevation platform on the surface, before the being placed in service, their duties and applications appear even more prominent.

A flying test bed constructed by refitting a B-6 was placed in use in 1970; after many years of improvement, the flying test bed is now equipped with frequency modulation and digital recorders, remote control systems, and real-time monitoring systems meeting international standards. It has greatly raised the effectiveness of test flights.

On the flying test bed, we have already completed debugging test flights and special test flights for two kinds of turbojet series and many kinds of engines. It is worth mentioning that a comparison with surface high-elevation platform testing results has solved controversial problems such as excessive engine gasping/shuddering, resulting in significant financial benefits.

In order to expand the scope of the use of flying test beds, in the early 80s we studied an engine that had been tested using the in-flight afterburning drag/rotational method, supplementing the insufficient speed and altitude range of the B-6 airplane.

### 4. Study of Compatibility Between Air Passage and Engine

In the last ten years, we have undertaken experimental studies on the F-7 and F-8 airplane models on topics such as the optimum adjustment pattern, patterns of air intake change, wave system organization and flow charts for air intakes, stable-state flow field distortion charts for air intake exhausts, and axially symmetrical air intake pressure distribution and wave system structure at large angles of attack. To carry out dynamic distortion studies, we designed a 48-point dynamic pressure rake with a six-point star configuration and a measurement system, and successfully measured the parameters for the exhaust cross-section dynamic distortion flow field of the air intake.

In the area of processing data on the stable-state distortion indices and the stable-state distortion charts, we have also prepared software for calculating the indices and drawing the intake flow field isobars and isopleths.



## 5. Test Flight Research on Engine Flight Load Registers

Since the middle of the 70s, the Test Flight Center has used flight measurement and testing to obtain a set of temperature, stress and vibration records for component parts and assemblies. The major measurement devices include a small-scale, non-contact telemetric system for the measurement of the temperature, stress and vibration of rotors rotating at high speeds, as well as advanced infrared measurement equipment (capable of reading 2000 K) that can undertake temperature measurements on blazing-hot components and afterburner combustion gases at the nozzle. In keeping with the development of research on the data for engine load, a national load data bank is obviously a great necessity.

## 6. Flight Testing of Engine Fuel Systems

This is one of the earliest programs developed in the area of test flight research for powerplants. For 30 years, not only has the Center carried out test flight programs for all models of planes, but it has also had the responsibility for a great amount of preliminary studies and special test flights. A total of over 30 experimental projects has been carried out on 14 plane models to date.

As early as fifteen years ago, fuel which we researched and developed on our own and lubrication compensation systems filled gaps in the field of experimental weightless aircraft, making a contribution to the development of our aerospace industry.

## 7. Surface Simulation Research

Over the last 30 years, the Test Flight Center has used a variety of experimental devices to carry out many series of large-scale surface simulation experimentation. These experiments are not only auxiliary measures for test flights; a high proportion of them are also a component of flight experimentation. For example, consider high-altitude fuel system experiments: It is possible to simulate on an experimental platform an altitude of 30 kilometers, with the fuel temperature equivalent to 80° C. It is also possible to perform simulation experiments for high-elevation fuel pump air blocks. Through experimentation, it has been possible to establish a standard experimental method for the comprehensive evaluation of fuels.

In the area of surface simulation experimentation for engines, the Flight Test Center currently has the trial-run capability for achieving a variety of objectives. An open-air standard test platform with side-wind equipment has been placed in service. The side-wind speed is adjustable, up to a maximum of 30 m/sec, and wind direction can be selected from 0° to 360°; the wind

source diameter is five meters. This 20-ton class open-air platform will become the standard test platform for undertaking calibration of engine thrust.

For over ten years, in the area of engine environmental simulation experimentation, we have been carrying out experiments such as engine icing; collisions with birds; smoke, water and sand inhalation; and damage by external objects. All tests have been successful and filled gaps in China's capabilities.

In the area of the effect of engines on the external environment, the Flight Test Center has successfully undertaken research sampling and analysis of aerial combustion gas, real-time sampling of gun chambers, and atmospheric analysis at airports. In the work of atmospheric pollution component analysis, it has been granted full monitoring privileges on behalf of the national environmental protection office.

## THE TEST FLIGHT CENTER'S FLIGHT SIMULATION DEVICES

Kang Dian Chen

The constitution and function of SB-6 flight control simulator, SB-100 air combat flight simulator and SB-300 flight training simulator at CFTRC are presented. [English abstract]

At CFTRC, flight simulation has become an inseparable part of the work of flight test research. Its main functions include: 1) To retrain test flight personnel, 2) to provide technical training for test flight personnel, 3) to review and eliminate mid-air breakdowns, 4) to carry out special research and investigate topics concerning limits, and 5) to perform research into test flight methods.

CFTRC has always emphasized the development of flight simulation, and has actively undertaken the construction of simulation installations. Furthermore, it has used these installations for over 40 simulation experiment projects on nine kinds of aircraft, solving many problems in the area of flight quality. We would now like to give a concise description of three of the Center's surface flight simulators.

The SB-6 Flight Control Simulator. The SB-6 is composed chiefly of the platform, the simulating computer, the instrument simulation system, the tracking display system, the measurement system and the corresponding electrical and hydraulic pressure supplies. The platform is a control simulation platform using three channels; the control system components of any kind of aircraft can be installed, and the control system parameters (including the rotation ratio, the friction, the weight of

unequal masses, gaps, rigidity, mass, aerodynamic hinge moment) can be conveniently adjusted. This makes the simulator adaptable to the characteristics of the control system of the simulated aircraft (See Fig. 1). The simulator computer is a mid-size simulator computer; it is also equipped with two non-linear devices. The tracking display system is controlled by one single-board microcomputer; negative pole radiation tube and digital tube display are used. On the fluorescent screen, the "enemy plane" is a circle with an adjustable diameter, able to



Fig. 1. The SB-6 Flight Control Simulator

move in more than ten patterns selected by a switch. "Our plane" is a section of line, moving according to the tested plane's angles of pitch, inclination and yaw. During testing, the pilot controls "our plane" in tracking the "enemy plane." After the line overtakes the circle, when the firing button is pressed on the pilot's stick, the "enemy plane," when hit, grows bright and flashes. The digital tube display outputs the number of hits. The computer also makes it possible to calculate tracking effectiveness.

The SB-6 may be used to test the control characteristics of aircraft, and evaluate operating systems and post-integration flight quality. It can be used to detect and eliminate deficiencies and malfunctions in operating systems.

SB-100 Air Combat Flight Simulator. The SB-100 Air Combat Flight Simulator is composed of the platform, the seating compartment, the instrument simulation system, the scenery viewing system, the target simulation system, the acoustical simulation system, the computer system, and the corresponding electrical and hydraulic pressure supplies. The platform is a general (multiple-purpose) control simulation platform equipped with six channels. It is possible to implement

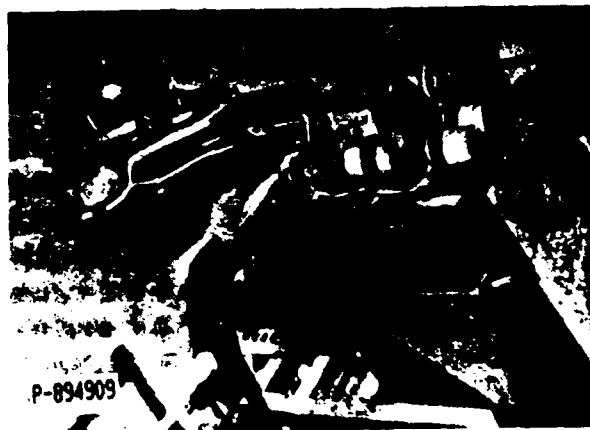


Fig. 2. SB-100 Air Combat Flight Simulator

physical simulation of the plane being tested. On the platform are installed the components of the airplane operating system; the main parameters of the operating system are brought into line with those of the airplane being simulated, thereby giving the sensation of the deflection of the plane's rudders and of pilot operation. The seating compartment is installed on a fixed horizontal platform; by means of changing the arrangement within the compartment, it is possible to convert the compartment easily so that it resembles the cabin of the airplane being tested.

The scenery viewing system is chiefly composed of a ground/sky scenery rotating platform and a 10-meter-diameter hemispherical screen. The ground/sky scenery rotating platform is a point-light-source structure with six independent double-painted spheres. The ground/sky scenery rotating platform is controlled by the airplane's attitude. The light emitted by the point-light source passes through the painted sky scenery and the ground

scenery spheres, and is projected on the hemispherical screen, forming a lifelike skyscape and landscape with a horizon. It can be used as a background for flexible aerial flight simulation and tracking targets.

The target simulation system uses a three-dimensional target model operated by six independently moving structures, photographed by a camera and projected by a projecting television on a 1-meter-diameter hemispherical screen. The motion of the target can be controlled according to a fixed pattern, or by the target operation platform, with control undertaken after the corresponding position and attitude of the simulated plane has been calculated by the main computer.

The acoustic simulation system uses composite sound technology and is able to simulate the sound produced by an engine, the sound of the landing gear being retracted, etc. It is used to intensify the reality of the simulation.

The computer system includes the computer, the interface, and the software. The software includes the application programs composing the flight system, the engine system, the scenic system, the target system, the instrument system and the acoustic system, as well as a real-time operating program and a variety of monitoring programs.

The chief use of the SB-100 is to study the flight quality of planes in the A and B flight phases, target interception and tracking performance in aerial combat, and flight control system capability and its effects on flight quality.

SB-300 Flight Training Simulator. The SB-300 Flight Training Simulator is composed basically of the seating compartment, the instrument simulation system, the sound simulation system, the scenery system, and the computer system. The arrangement of the seating compartment, in its interior environment, is entirely identical with the airplane cockpit; it uses a changeable cockpit control stress loading system to give the pilot the sensation of control, offering the main computer control displacement. The entire seating chamber is placed on a four-wheel vehicle.

For the scenery system, a computer imaging system is used, with three-channel, three-window virtual image display. The vertical angle of the field of vision is  $30^\circ$ , the horizontal angle for the field of vision is  $120^\circ$ , and the brightness is  $20.6 \text{ candles/m}^2$ . The frame frequency is 25 frames/second. For each channel, it is possible to display 300 planes and 1600 points of light. It is possible to simulate day, dusk, and night settings, and visibility is adjustable. The scope of the ground scenery is  $64 \times 48$  square kilometers. A partial three-dimensional ground grid and a three-dimensional target plane are provided. The sound

simulation system is comparable to that of the SB-100. The computer system includes computer, interface and software.

The chief use of the SB-300 is training test flight pilots and undertaking phase C flight quality research. Thanks to the ease with which the seating compartment and a portion of the software can be changed, it is possible to provide a test flight for any kind of fixed-model combat plane, to train test-flight personnel, and to prepare a general scheme for training.

As China's aviation industry develops, CFTRC not only will make great improvements in the simulation equipment for military test flights, but will also develop civilian flight simulation devices, making a still greater contribution to the industry.

## TESTING RESEARCH TECHNIQUES FOR FREE-FLIGHT MODELS

Yu Zhidan, Liu Zhu

This paper briefly described the development of testing research technique for free-flight models in CFTRC. It mainly introduces the associated test models, the present status of experiment and measurement technologies and the prospects of future development [English abstract].

Testing research for free-flight models at CFTRC has developed on the basis of carried-model test flights. This research has now been in progress for over 20 years. For 20 years, stall/tailspin research has been carried out on almost all models of China's domestically manufactured planes. Other research programs have been developed at the same time, achieving relatively great progress in the field of experimental research technology.

### TEST MODELS

The earliest test models were wooden structure models. They were equipped with a remote-control receiver, three control rudders, a recovery parachute, and a large number of DC electrical cells. Some were equipped with heavy lead batteries. This kind of model was able only to carry out fixed research programs. Along with the development and dissemination of glass fiber reinforced plastic technology, wooden models were gradually replaced by plastic models. The model fuselage with the exterior reinforced plastic shells offered a large, useful internal area, structural strength, ease of maintenance, and appropriateness for small-batch production. Like some light-model aircraft, they were light in weight and had a small wing load; it was also possible to use flight model structural models (for the fuselage exterior, wood of low density was used) as free-flying test models. The scale of the test models was generally between 1/15 and 1/14, and weight ranged between 30 and 70 kg.



Fig. 1. Installation of sensor for angle of attack and angle of sideways slippage on a model.

## TESTING TECHNOLOGY

### Selection of the Model Carrier

The early period test models were carried by small-scale transport aircraft to 700-1000 meters, and were controlled by the pilot of the carrier plane via a release button. On the carrier plane were installed elevator structures. At the time of takeoff, they were placed in the extreme upper position. After takeoff, to avoid the effect of the propeller slipstream and the air flow of the lower part of the fuselage, the models were lowered into the extreme lower position. After release, the model's flight was controlled by surface control personnel using remote control. At this time, the carrier would make a sharp turn, distancing itself from the model. Generally speaking the use of small transport planes to carry small combat plane models was very convenient; but for large-proportion models or light-weight plane models, it was best to use helicopters to carry them aloft, or to tow and release them. When using helicopters to carry the model, a very low release speed can be used; suspension release is even a possibility. This avoids restrictions imposed by the height of the model's vertical tail.

### Remote Control Technology

The remote control apparatus used in the early period was the BJ6401 double-path simultaneous ten-channel key-controlled equipment with audio frequency signal modulation and low stability. At the beginning of the 70s, we switched to the BJ6900 model. The control method used was the pulse step jump style. With respect to the control surfaces, there were only two positions, the neutral and extreme side positions. For this reason, there was no way to simulate rudder deflection speed; just as the "slow pull-rod stalls," this kind of control action could not be achieved. In 1976, we imported sample remote control equipment; we were not only able to implement rudder surface control along the lines of the sample, but were also able to achieve stability and reliability, and resistance to interference could be improved.

### Recovery Technology

Ordinarily, a drag parachute is used for recovery. On the basis of the parachute's resistance coefficient and the rate of descent, it is possible to determine the surface area of the parachute. To guarantee that the parachute will open reliably, in addition to a parachute-opening installation with a remotely induced explosion, a fixed-altitude parachute opening device has



also been added. In recent years, research has been carried out on the feasibility of "wing-shaped parachutes" for recovery and glider wing landing, as well as impulse-activated nets. Currently, the average crash rate for free-flight research models has dropped to between 8 and 10%; that is, on the average, there is one crash for each 10 to 12 flights.

## MEASUREMENT OF PARAMETERS AND DATA PROCESSING

Progress in contemporary free-flight model research technology is revealed mainly in the technologies related to measurement of parameters and data processing.

### Measurement of External Parameters

At the beginning of the 70s, CFTRC installed an elevational and directional potentiometer on an old antiaircraft gun mount, replacing the camera support of the 60s and thus improving photographic conditions. In 1976, it developed the double-platform model SB-81 photographic theodolite which was able to measure distances accurately and distinguish movement and paths, and recover model parameters such as the tailspin diameter, the rate of descent, and the time for a complete tailspin at the same time. Currently, we are in the process of developing still more advanced equipment for the measurement of external parameters.

### On-Board Testing Technology

At the beginning of the 70s, CFTRC for the first time installed an automatic recorder for the angles of elevation and sideways slippage on the FT-6 free-flight test model; and for the first time successfully recorded changes in the angles of elevation and sideways slippage in model tailspin. In the mid 70s, this device was used to undertake full-scale tailspin test flights.

The results of the test flight measurements were in agreement with the results from the free-flight model. In the report on the model's loss of velocity and tailspin, the account of the velocity-loss characteristics was almost identical to the account in the report on the tailspin test flight in the full-scale plane.

The use of models made of fiber glass reinforced plastics made it possible to expand the scope of on-board testing. In line with this, the quality of sensors and recording devices was improved. Small-scale on-board oscillographs are able to record twelve parameters at a time, chiefly including the angle of attack, the side-slip angle, the triaxial rate of angular rotation around the fuselage, the angle of elevation, the angle of roll, the tri-

directional overload, and the deflection of each rudder surface. Thanks to these capabilities, the research on free-flight testing has completely entered the phase of quantitative studies.

In the 80s, CFTRC installed a YT-2 micro-scale remote-control launcher equipped with a telemetric vehicle and a telemetric surface station. It can be used effectively in data collection, with a measurement precision higher than that of photometry; thanks to computerized assistance, it represents a great saving in the quantity of work required.

To improve the model's recording system still further, we began in 1985, on our own, to develop the JCX-5-CJ micro-computer data system. The measurement parameters can be combined automatically according to the frequency value; each time, it is possible to record 20 independent parameters and five switch quantities. Even under conditions in which a telemetric station is not available, it is still possible to process data directly with the microcomputer. In comparison with the telemetric system, the microcomputer system lacks a signal transmitter and a receiver; the measured data is temporarily stored on the model, which has greatly reduced the rate of failure.

Compared with on-board magnetic recorders, the microcomputer's measuring device is smaller in volume and lighter in weight; further, its data capacity is greater beyond all proportions than that of a small magnetic tape. The model stall/tailspin test results for several domestically manufactured combat planes show that the microcomputer data storage device has produced great benefits in raising the quality of free-flight model test flights and reducing the duration of the testing period.

#### CONCLUSION

Currently, CFTRC is able, unassisted, to design and develop a variety of research models. In the area of experiment content, it is able to undertake extensive free-flight model research on the major angle of attack stall/tailspin for all types of aircraft. It is also able to undertake the related research in the area of anti-tailspin parachutes, providing reliable experimental data for establishing the design parameters for such devices. Currently, the Center is in the process of undertaking quantitative research for the vertical and horizontal directional aerodynamic derivatives of aircraft, as well as free-flight model research for powered models.

Horizontal free-flight testing has become an indispensable part of China's research tools for developing new planes. We can predict that in the area of future development in high-technology aviation and aerospace, it will be given a prominent position.

## AIRCRAFT ENGINE ENVIRONMENTAL AND INGESTION TESTING

Wen Xiao, Hua Yutian

In recent 10 years greater progress has been made in aircraft engine environmental and ingestion tests in China. This article describes some achievements in carrying out environmental icing, bird ingestion, atmospheric water ingestion, sand and dust ingestion, armament gas reingestion and foreign object damage tests. Some methods and equipment of the tests are also presented [English abstract]

A great variety of environmental factors affect the performance and reliability of aircraft engines in use; and the noise and exhaust gases the engines generate pollute the environment as well. In the Aviation Engine General Use Specifications published by our government, environmental testing accounts for a total of 12 pages; the topics include high and low temperature starting tests, environmental icing tests, corrosion sensitivity tests, bird ingestion tests, tests on damage caused by foreign objects, ice ingestion tests, sand and dust ingestion tests, water ingestion tests, armament gas reingestion tests, operating noise analysis, exhaust gas pollution, and survival performance testing after nuclear explosions. These testing projects all incorporate strict, specific experimental conditions and standards of compliance. In order to undertake certain projects within these tests, CFTRC has explored and selected a set of experimental methods, and has constructed testing equipment capable of simulating environmental conditions.

In recent years, CFTRC's work in the field of engine environmental research has chiefly included engine environmental icing protection, bird ingestion experiments, armament gas reingestion tests, water ingestion tests, sand and dust ingestion tests, and foreign object damage tests; of these, the bird ingestion tests, the sand and dust ingestion tests, and the water ingestion tests were awarded the Success in Science and Technology Award from the former Aviation Industry Ministry.

### ENVIRONMENTAL ICING TESTING

For engines, the formation of ice occurs mainly at the mouth of the air-intake passage, the air-intake flow adjustment support, the I and II rank rotor blades of the axial flow air compressor, and the forward edge of the stator blade. The formation of ice can present an extremely dangerous threat to the engine: When there is a slight coating, it may reduce engine performance and even cause flameout; and when there is a heavy coating, it may make the engine gasp/shudder and lead to severe wear and damage.

In order to test the ice protection system's working capabilities, the Flight Test Center uses the environmental icing protection testing methods under conditions of earth-surface atmospheric temperature; that is, with the atmospheric temperature below 0° C, on a surface engine testing platform, at the intake of a working test engine, an air mass containing super-cooled water droplets is created, causing the components within the engine passages to ice up; the engine's performance is then measured, the engine's ice-protection system is turned on, and the ability of the system to eliminate ice is studied for conformity with the specified requirements.

For this purpose, we have developed a system for water misting/temperature reduction capable of forming engine ice at engine intakes. This system consists of a water supply system, a misting grating, temperature reducing equipment, and a sampling staff. It is able to supply the engine with the required super-cool water droplets (effective average diameter 20-30 microns) and to produce the atmospheric water capacity required by the specifications. At the time of testing, water at a specified temperature is transported into the misting grating via a tube from the water supply system; it is misted to form 10-60 micron water droplets, and then, via the refrigerating equipment, is changed to 0° super-cooled water drops. These super-cooled droplets are agitated in the engine's air flow, and form a layer of ice on the engine components.

Using the testing equipment on domestically manufactured engines, we have successfully undertaken anti-icing experiments. The equipment offers convenience in observation and testing; results are easily repeated. The danger is small, in comparison with flight testing. In comparison with high-altitude platform and ice/wind tunnel experiments, testing costs are economical.

#### BIRD INGESTION TESTING

Aircraft speed is increasing constantly, and the collision of bird and plane is an ever more serious factor in airplane damage.

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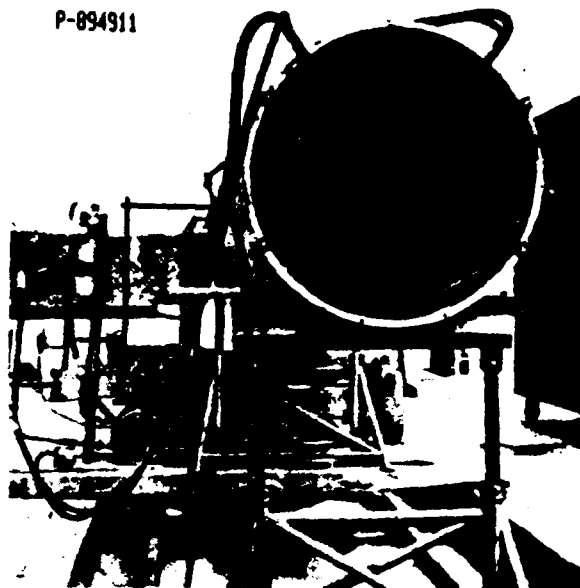


Fig. 1. Engine environmental icing testing

A bird being ingested into the engine has even caused crashes at times throughout the world. The specifications require that after an engine has ingested a small bird, some of the components may be damaged, but the airplane must not suffer harm.

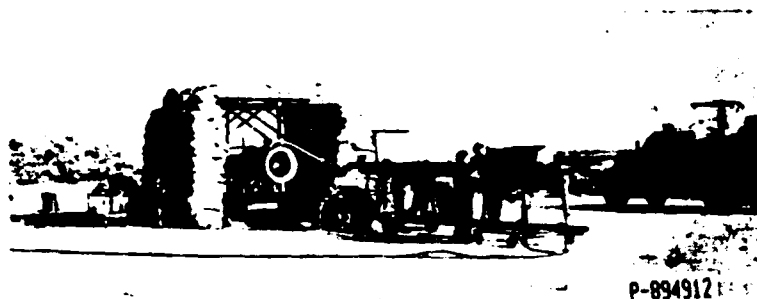


Fig. 2. Engine undergoing bird ingestion testing.

Bird ingestion testing for engines is ordinarily performed out of doors on a testing platform. The Flight Test Center uses a bird-caster which is a large-caliber air gun (consisting of an air tank, a gun tube, a control structure, and

other associated equipment). The air tank is full of dry air at the required pressure. During experimentation, after the control structure is activated, the air under pressure bursts out and causes the hollow, soft plastic sleeve loaded with the test bird to accelerate along the gun tube, reaching the speed prescribed in the standards at the mouth of the gun and crashing into the forward part of the engine. The bird's speed is produced by the air pressure controlling the air storage container, and measurement is performed by a high-speed camera. This equipment has been used for bird casting tests for two kinds of domestically manufactured engines. The tests use a chicken as the bird. The tests showed that the equipment completely satisfied the requirements specified in the standards.

#### ARMAMENT GAS REINGESTION

When an aircraft launches a weapon, the weapon emits a great amount of scorching hot exhaust. After the engine sucks in these gases, the intake temperature rises sharply, resulting in a reduction of the rotational speed. The air flow is reduced, causing an increase in the combustion chamber excess air coefficient and possible flameout in the combustion chamber. In addition, the general pressure decreases, leading to a reduction in axial airflow and increasing the inequality in pressure field and temperature field. Under these conditions, it is very possible for the air compressor to enter an unstable working condition. It follows that armament gas reingestion experiments must be carried out to ensure that reingestion does not induce

engine stalling, gasping/shuddering, flameout, or mechanical damage.

Currently CFTRC is able to perform experiments of this nature on a surface testing platform and flying test bed.

The method used is to install a high-temperature combustion gas generator in front of the engine to be tested. The temperature,

chemical components, etc., of the high-temperature combustion gas that it generates are the same as those produced by firing a weapon. The generator is composed of a simulation shell, a gas accumulator, a smoke delivery conduit, an ignition device, and so on. During experimentation, a small rocket simulation shell is ignited, and the high-temperature exhaust is forced into the air intake of the engine from the gas accumulator via the smoke delivery conduit. The amount of smoke produced by the shell and the temperature of the combustion gas are determined by the size of the charge. The simulation shell requires 0.1 second for complete combustion. Because the time that the engine operates in an unstable condition is only 0.1 to 0.2 second, a highly sensitive measuring system has been selected to collect the instantaneous change parameters for the engine. This set of equipment has been used to carry out successful experimentation on a large number of models of domestically manufactured engines.



Fig. 3. Armament gas reingestion experiment.

#### WATER INGESTION EXPERIMENTATION

When a plane flies in the rain or taxis on runways with accumulated water, the engine may suck in large quantities of water in a liquid state. When a working engine takes in large quantities of low-temperature rain water, the resulting drop in temperature may cause the engine housing and the component parts and assemblies at the hot end to undergo sudden contraction, excessively reducing the gap with the blade tips. This in turn causes damage owing the friction between the blade tips and the interior wall of the engine housing. Large quantities of water entering the combustion chamber lowers combustion efficiency and may even cause flameout and stop the engine.

When experimenting with water ingestion, the amount of water introduced into the engine should be 5% of the air flow by

weight, and 50% of this liquid-state water should be supplied to a sector representing  $1/3$  of the air intake.

The water ingestion equipment used in the experiment consists of a water nozzle ring/flow adjustment assembly, hydraulic pressure water tube, a flow measurement

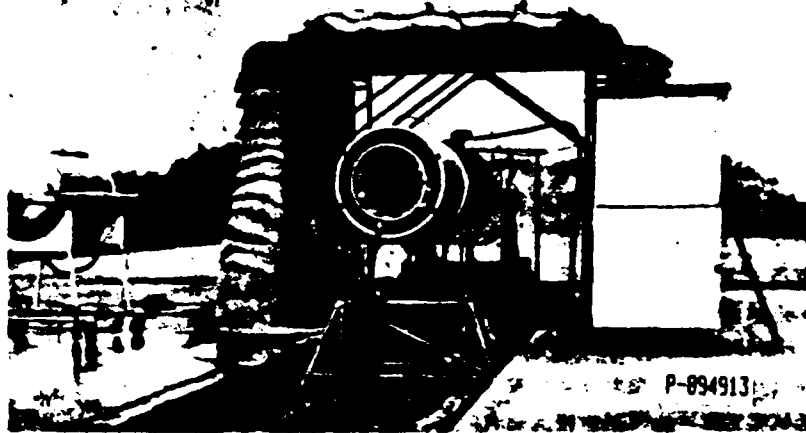


Fig. 4. Engine undergoing water ingestion testing.

installation, etc. During the experiment, the engine is installed on a test platform in the open. On the housing of the air compressor are affixed an axial and a radial strain plate to measure the amount of contraction of the engine housing when water is ingested. After the engine has been brought up to its working state, the electronic water injection valve is operated and the water in the reservoir enters the nozzle ring/flow adjustment assembly under pressure via the flow measurement installation. From there, it is sprayed into the engine's air intake flow. The amount of liquid water injected into the engine's air flow is controlled by the pressure in the reservoir.

#### SAND AND DUST INGESTION TESTING

When an engine is used, a large amount of sand and dust enters it in the air flow, which severely wears and corrodes the blades of the air compressor. At high temperatures, the sand and dust melts and adheres to the turbine blades, possibly changing the shape of their surface and causing them to deviate from their intended form, thereby reducing efficiency. Sand and dust remaining in the engine form a core upon which steam can condense, which may cause the surface of the engine to rust more rapidly.

The sand and dust ingestion equipment which the Test Flight Center has developed is used on a surface testing platform. The equipment consists of a sand chest, an adjustable constant sand supply installation, a sand and dust nozzle, an air cleaner, a vacuum sand delivery device, etc. In an experimental run, when the engine is exerting its maximum thrust, the sand and dust ingestion equipment supplies sand to the engine intake at a rate

of 0.053 grams of sand per cubic meter of air. After the sand and dust mix with the main air flow, they are sucked into the engine. The constant sand supply installation can be adjusted to feed a quantity of sand based on the air flow of different engines. In the most recent experiment, which lasted four hours, the engine ingested over 30,000 grams of sand and dust. This equipment is able to distribute evenly the exact amount of sand and dust prescribed by the regulations in the engine's air intake flow, satisfying the experimental requirements for different model engines.

#### FOREIGN OBJECT DAMAGE TESTING

When an engine is in use, it is inevitable that it will ingest a wide variety of foreign objects. Based on incomplete statistics from the Chinese Air Force for 1978 and 1979, there were 70 accidents involving engines being struck and damaged by foreign objects. In these accidents, the fan blades, the air compressor rotor blades, and the stator blades were the most likely to suffer damage.

When there is blade damage from a foreign object with a minimum stress

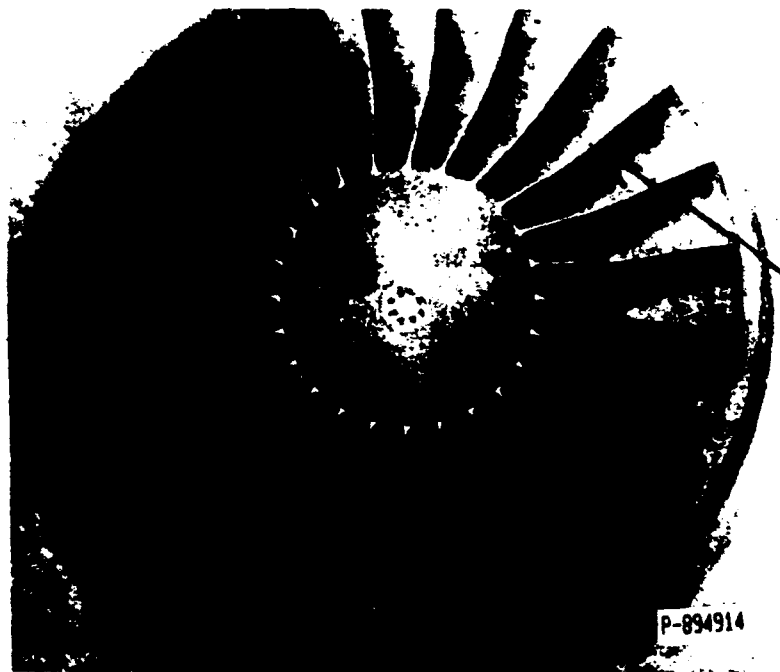


Fig. 5. Foreign object damage testing. (The arrow shows the location of slotting.)

concentration coefficient of 3, two cycles, as defined in the regulations, are required as the time the engine should be able to continue to function; optionally, a number of hours is prescribed. In order to satisfy these requirements, before the experiment a slot with a stress concentration coefficient of 3 was created artificially on the blade. Then the experiment was carried out in accordance with the working period specified as normal for the model. The key in this method is to research a set of quantitative formulas for calculating the relationship between the size of the slot in the blade and the stress



concentration coefficient, as well as a method of verification. After study, we now understand this method of making calculation and providing experimental proof, and we have developed an accurate method. In December 1988, on the first rank of a certain engine model, we made a slot of the size obtained by calculation. The stress coefficient at the location of this slot was 3, and we operated our engine on the test platform for two cycles. In the experiment, the vibration value of the engine increased from its initial 2.09 to 2.99 at the conclusion of the experiment, and there were no other abnormal conditions.

#### OTHER EXPERIMENTS

Currently, engine environmental testing projects that are being developed further by the Test Flight Center include experiments on corrosion sensitivity, ice ingestion tests, operating noise analysis, exhaust pollution, high and low temperature starting, test for survivability after nuclear explosions, and others. We anticipate that these projects will all be completed in the near future.

## TEST FLIGHT TECHNOLOGY FOR AVIATION ELECTRONICS EQUIPMENT

Wang Guangxue

The avionics flight test constitutes an indispensable part of the whole flight test program. In this article, the test equipment and testing ways for aircraft antenna, radio communication equipment, navigation system and airborne radar used by the Center are introduced. The static electricity discharge and anti-lightning measures and test methods are also explained [English abstract].

The work of testing aviation electronics equipment is an important part of flight testing. In this area, most important research carried out by the Test Flight Center includes experiments on aircraft antennas, communications equipment, navigation systems, and high-voltage static electricity technology.

### AIRCRAFT ANTENNAS

CTFRC has an expansive antenna test field equipped with a complete set of advanced antenna testing systems and installations capable of measuring all parameters for on-board antennas and performing flight test experiments. It is possible to perform surface antenna tests for the entire aircraft, reducer scale-model experiments, and flight test experiments. The development of the communications aerial for the first elementary-level training airplane developed in China and the test flight for determining its installation position were performed here. For the past thirty years, CTFRC has been responsible for over 30 antenna research, experimentation and evaluation testing programs for 15 models of aircraft. It has also developed single, double, triple and quadruple frequency section antennas as well as combined compass/communication antennas; these can be used together with all domestic and foreign transceivers. In the area of antenna test flights, a series of antenna directional chart test flight methods has been developed, including the circumferential flight method, the figure-eight flight method, the "plum-blossom petal" flight method and the polygonal flight method; in addition, the Center



Fig. 1. The CTFRC's antenna testing field and antenna test equipment.

uses the method of automated aerial recording of flight attitude and synchronous surface recording of field strength. CFTRC has also successfully appraised two types of aircraft antennas from Marconi of the U.K. The Center has made progress in the work of researching self-adapting antennas, composite aircraft antennas, and other new antennas.

#### FLIGHT TESTING ELECTRONICS EQUIPMENT

CFTRC has, to date, performed over 100 evaluations of domestically manufactured electronics equipment, and has had the responsibility for appraising the 7M radar and AD3400 communications transceiver from Marconi (U.K.). In addition to setting up a very complete surface/flight testing installation, the Center also has two imported electronic test planes for research and calibration test flights for electronics equipment involving communication, navigation and radar and for qualifying evaluation flight testing; the planes are also able to calibrate air field surface navigation equipment and undertake the work of aerial survey photography. In recent years, the Center has also advanced the study of special dynamic measurement technology for airplane radar targets.

In the area of communications, the surface radar and time adjustment charts track the position of experimental aircraft; automatic on-board recording of aircraft flight parameters and voice signals is used, and standard voice comprehensibility experiments have been brought into play to determine communication distances and quality. The surface laboratory has a special system to test receivers and transmitters, a noise measurement system, and other special equipment. It is able automatically to measure all parameters of communications equipment in all frequency ranges, helping the technician analyze failure and evaluate quality in communication equipment and ensuring the uninhibited progress of the work of flight testing.

In the work of flight testing radio guidance equipment, modern equipment and methods have gradually come into use. Examples include radio altimeter flight testing. During flight testing over land, the aerial photography method was used for visible targets; during flight testing over water, the surface-to-air photography method was used. In addition, the laser altitude measurement method and others were used. The aerial photography method, the radar measurement method, and the plum petal flight method were used to calibrate the precision and effective distance for compasses, takang [transliteration], and other guidance equipment. For Doppler guidance radar and guidance systems, the four-point surface method and the three-point line method from analytic aerial photography were used, as were the radar measurement method, the photometric method, and the ratio method. In the development and qualifying evaluation test

flights of the model 203 Doppler radar, the three-point line equation's single rear-exchange analytic photographic method and the radar tracking method were used. The plane's six external position elements that were obtained were relatively precise. The Center also has a unique communications/guidance device for aerial guidance experimental platforms; it is used to calibrate and test all surface guidance stations at airports.

In the field of radar test flight, data gathering systems and photographic and video frequency recording systems are used on board to record radar parameters and aircraft attitude data by means of a variety of sensors. On the surface, measuring radar, optical theodolites, laser theodolites, radar relay stations, radio response range finders, and laser range finders are combined with data collection systems to form measurement systems; air-ground measurement is carried out synchronously, and evaluation test flights are performed for radar measurement speed, positional and range finding accuracy, etc. In addition to domestically manufactured systems, successful flight evaluations have been performed on the fire-control system manufactured by Marconi.

#### AIRCRAFT STATIC DISCHARGE AND RADAR PROTECTION

Static discharges and radar protection are important means of safeguarding aircraft flight. The Test Flight Center has a high-voltage static electricity laboratory equipped with a high-voltage D.C. generator, current-measuring equipment for aircraft discharges, and apparatus to measure the noise of dischargers. Outside the laboratory, there is a rope-cable crane with a height of 40 meters, capable of suspending aircraft for static discharge experimentation. A large variety of aircraft have been subjected to static electric experiments, and the performance of dischargers has been studied. Evaluation experiments have been carried out on static electrical dischargers, and flight testing has been performed on static electrical flow. In addition, experiments have been carried out on scale models of the F-8 and other planes for lightning adhesion points.

As on-board electronics equipment continues in the direction of functional combination and digitization, the task of performing combination simulation and test flights to develop electronics equipment has become increasingly important. Because of this, the Flight Test Center will study new flight test methods for use on composite electronics aviation equipment in order to develop surface simulation equipment, computer simulation equipment, and aerial simulation experiments to reduce the actual amount of test flight work, shorten the test flight cycle, raise test flight effectiveness, and plan the refitting of several large-scale electronics testing aircraft. Furthermore, CFTRC will actively

develop international cooperation and raise testing to a still higher level.

## FLIGHT TESTING OF EJECTION SEAT SYSTEMS

Qiu Ping

Since 1968, a number of ejection seat flight tests have been performed in China. A B-5 bomber was converted into an ejection test vehicle. Now, a new one is being built to meet future test requirements [English abstract].

The testing of ejection seat systems can be classified into research testing and evaluation testing on the basis of the nature of the test, or -- on the basis of the measures used -- into wind-tunnel tests, rocket powered surface vehicle tests, and flight tests. Each of these classes has its own special features; of them, flight tests are the most important.

Flight testing of ejection seats is performed under actual or nearly actual conditions of use. The experimental results are very significant in the determination and evaluation of the performance of components, subsystems and the entire system. For this reason, it plays an indispensable role in the development of ejection seat systems, and is a very important part of the final evaluation of the system.

China's involvement with the developmental work on ejection began in the 60s, and toward the end of the decade began to include the design of rocket-powered ejection seats. In 1968, we successfully converted a B-5 aircraft into an ejection test



Fig. 1. B-5 ejection test vehicle.

vehicle (see Fig. 1). It had two test compartments: One behind the pilot's compartment and the other behind the vertical fin. The choice of which to use was based on the contents and purpose of the experiment. This innovation was not found on foreign ejection testing planes. The forward compartment is normally used for ejection tests for the emergency

system. The rear compartment is affected by the vertical fin, and is ordinarily used for testing components and subsystems that do not have strict aerodynamic requirements and for ejection testing related to the acceptance of measurement equipment. In addition, the rear chamber makes it possible to carry out human ejection testing with relative safety. On the plane is installed a variety of measuring equipment that can record flight parameters and state parameters during the flight. The refitting

of our ejection test vehicle was successful in providing the material conditions for any possible series of flight tests.

Toward the end of the 60s, China performed its first mid-air ejection test. It subsequently performed evaluation tests on the F-8 emergency system (two ejection styles: Open and with cord) and verification tests for the F-7 ejection seat.

At the beginning of the 70s, evaluation tests were performed on the A-5 ejection seat and verification testing was performed on the F-6 ejection seat. In-flight ejection testing with mannequins was also carried out on China's first rocket-powered ejection seat. The speed of the aircraft during the tests was 500 km/h at an altitude off 1200 m. Afterward, to ascertain the life-saving performance of the rocket-powered ejection seat, an in-flight ejection experiment with an animal (monkey) was carried out; this time, the speed was 500 km/h and the altitude was 800 m. Subsequently, an extremely successful ejection test with a human subject was performed, with a speed of 500 km/h at an altitude of 1000 m.

At the beginning of the 80s, in order to determine the emergency capabilities of China's model II rocket ejection seat at zero altitude and low speed, we performed four surface ejection tests on runways at a speed of 120 to 180 km/hr.

We also performed validation and evaluation testing of the FT-6, B-5 and B-6 ejection seat and four kinds of rocket ejection seats on the B-5 ejection test aircraft, as well as many special ejection tests such as parachute strength ejection tests. To date, a total of over 180 tests have been completed. These tests have been very important in the study and development of China's aviation emergency systems. Nevertheless, the B-5 test plane's test speed (ground speed of 400-680 km/h) and test altitude (relative altitude 1000 to 5000 m) are rather limited; nor can the plane perform ejection testing under conditions of evasion. Therefore, it is far from satisfying the demands for emergency system research and evaluation testing. To improve this situation, we began in the middle of the 70s to consider new ejection testing aircraft. At the beginning of the 80s, we officially began the work of studying the new aircraft. Not long afterward, the FT-6 was successfully converted to



Fig. 2. The FT-6 ejection test aircraft.

an ejection test aircraft and performance testing was undertaken (see Fig. 2). Its maximum testing speed was 1000 km/h and maximum altitude was 10,000 m. This plane, after ejection acceptance testing, was at once placed in service. It will be used chiefly in high-speed ejection tests under all types of maneuvering conditions, and so will greatly enhance China's test flight capabilities for aviation emergency systems and provide favorable conditions for future research in the field.

Second to the testing aircraft itself, mannequins are an important piece of equipment in flight testing ejection systems. They are prepared in accordance with the statistics for the physical measurements and weight of aviation personnel. The Test Flight Center has constructed many mannequins since 1964; they were of great use in China's early research on ejection systems.

Relevant surface testing equipment is also required for emergency system flight testing. Before in-flight tests, it is ordinarily necessary to perform several preparatory experiments, such as using measurement equipment to study the ejection test. For this reason, we designed and built -- without foreign assistance -- a large-scale vertical ejection platform in the early 60s (see Fig.



Fig. 3. Large-scale vertical ejection platform.

3). It was 34 meters high and had an angle of inclination of 17°. It was a multi-purpose experimental device used principally for experiments with the performance of ejection activation installations of emergency systems. The maximum permissible ejection weight was 240 kg and the maximum permissible ejection speed was 24 m/s. This device could also be used to perform investigatory ejection testing on emergency system components or subsystems, ejection training for aviation personnel, and check-out testing of related measuring equipment. This platform was used for over 20 items of research; over 1200 ejection test runs were carried out.

To ensure the effective performance of tests, the Test Flight Center has developed many kinds of overload sensors, angular velocity sensors, parachute-opening dynamic load sensors, emergency ejection telemetric systems, emergency ejection magnetic recording



systems, small-scale photographic theodolites, and other measurement equipment and devices.

Currently, the Test Flight Center is engaged in further study of how to implement pre-testing aerodynamic gust protection, how to enhance the simulation capabilities of mannequins, how to undertake experimental data collection more effectively, how to perform emergency ejection testing experiments under flight conditions, and other problems.

## ON-BOARD TESTING TECHNOLOGY

Sheng Qianguo, Huo Peifeng, Wu Lianyong

In flight test, the results and correctness of its conclusion are very much influenced, to certain extent even determined, by data measuring method, testing technique and equipment. The development history, current status and test techniques for small and large size aircraft in the Center are introduced. Some pictures of the test planes used in the flight test are also shown [English abstract].

In flight testing, regardless of whether it is qualifying evaluation or preliminary research testing, the work of measuring is essential. The methods of measurement and the testing technique and equipment have a direct influence on the test flight results and accuracy of the conclusions. Measurement is extremely important for flight testing. As flight testing becomes more thorough, it makes new and even higher demands on measurement; the progress of measurement technology and equipment, on the other hand, spur on the development of flight testing.

### THE CURRENT STATE OF ON-BOARD MEASUREMENT EQUIPMENT

The Test Flight Center's measurement equipment has passed through a developmental process from automatic recorders and optical oscilloscopes to magnetic recording equipment. In the 60s, an analog aviation recorder with 14 magnetic channels was deployed for use in vibration measurement. A digital magnetic recording system was placed in use that was able to measure 30 analog and digital parameters; it had a composite sampling rate of 300 bps and used the parallel and serial methods of recording. A modular on-board data collection system was also placed in operation; it had a maximum capacity of 256 channels and a composite sampling rate of 2.56 kbps. These two kinds of magnetic recording systems are associated with surface data-processing computer systems. In addition, a PAM/FM/FM system high-capacity telemetric system and a broad-band frequency-separating telemetric system are linked with them. Since the 70s, an on-board PCM programmable data collector and a surface data processing system have been in use. The maximum capacity of this kind of on-board magnetic recording system is 1024 channels with a total sampling rate of up to 8 kbps. At the beginning of the 80s, an on-board real-time flight-testing data system (a Lishan [transliteration] composite measuring system) with telemetric technology and a computer as its core was deployed. It combines on-board magnetic recording and telemetry, and links a pulse-code system with a multiple-channel frequency-separating system. It combines telemetry with

a computer that has a real-time data processing capability, and is associated with a large-scale flight monitoring and control room, forming a large programmable composite system. It can measure 1024 analog and digital parameters of all types, and has a total sampling rate of 32 kbps. It can measure simultaneously several dozen acceleration/deceleration parameters. Common bus technology and modular construction are used for all components. An S-band telemetric system is used to transmit information to surface stations. The effective distance of the system exceeds 200 km. In the middle of the 80s, another composite on-board flight data system (the Qinchuan [transliteration] system) was installed. It features on-board real-time display and real-time data processing, and uses electronic programming. It has a total sampling rate of 125 kbps and can measure 4096 parameters. The system features ARINC429, ARINC575 and MIL1553B connections. In addition, the Test Flight Center also has in use malfunction recorders and measurement equipment used for ejection and model plane test flights. It therefore has powerful, advanced measuring capabilities and the means required for qualifying evaluation for all new aircraft and products and for engaging in all special research programs.

#### MEASUREMENT TECHNOLOGY FOR HIGH-MOBILITY AIRCRAFT TEST FLIGHTS

Test flights for highly maneuverable aircraft chiefly use on-board magnetic recording and telemetry; when required, malfunction recording equipment is also installed.

Normally, composite measurement technology and real-time telemetric data processing are used. To measure gradually variable and digital parameters, the PCM method is used, linked via a multiple-station collector to a common line; to measure speed variation parameters, many groups of multiple-channel frequency separator equipment are normally used. Of these, one group of signals is transmitted to the surface with telemetric real-time, and the others are recorded in parallel on the channels of an analog magnetic tape recorder for later processing. This kind of technology is especially useful for test flights for qualifying evaluation on new planes and large-scale programs. In the qualifying evaluation testing for the F-8 II, 17 tasks were carried out in combination on one airplane, and over 300 parameters were measured. In addition, the Test Flight Center also places great emphasis on the application of telemetric technology.

The Test Flight Center has at its disposal many experimental research planes; the refitted B-6 flying test bed is shown in Fig. 5 of the center insert [not included in translated material]. This test bed can suspend the engines of all models of aircraft for mid-air testing. The plane has a universal composite and multifunctional measurement system including a PCM

collecting subsystem, a multiple-channel frequency separating subsystem, and a telemetric transmitting and magnetic tape recorder; an on-board real-time data processing system based on a minicomputer can also be installed. See fig. 17 of the insert for an illustration of a part of the Lishan on-board equipment used on the plane [not included in translated material].

#### MEASURING TECHNOLOGY FOR LARGE AIRCRAFT TEST FLIGHTS

In airworthiness test flights for large civilian aircraft, a composite on-board data system with real-time display and real-time data processing capabilities is used. This system consists of a PCM data gathering and recording subsystem and a real-time data processing subsystem. The PCM data gathering subsystem is able to use a number of collecting devices together via a common bus. Its capacity is 4096 with a total sampling rate of 120 kbps. It can measure parameters for changes in velocity and transition. The on-board real-time data processor subsystem is a complete data analysis and monitoring system organized around a 32-bit VAX minicomputer. It is able to display physical quantities and calculated results in real time, raising test-flight effectiveness and ensuring test-flight safety and quality.

In addition, in test flights of civilian aircraft, the Test Flight Center's air-speed measurement system has attained international standards; it is able to measure accurately dynamic and static pressure and provide precise flight altitude and speed measurements. It is also able to calibrate the plane's airspeed system. It uses a screen-style airspeed tube total-pressure system and a tail-fin towed cone static pressure system. Figure 13 of the center insert [not included] shows the towed cone static pressure system installed on a Y-7. For checking and setting the center of gravity, the total weight of the aircraft and automatic center of gravity control system is used; the center of gravity adjustment range is 15-30% and the rate of adjustment is 1%.

The Test Flight Center, in addition to its domestic test flight duties, undertook evaluation test flights for the Marconi MADS-7 electronic defense system at the beginning of the 80s. This system is composed of ten subsystems, and is installed on the F-7 II. Test flights measured 137 parameters, providing an accurate basis for model definition.

## DATA PROCESSING TECHNOLOGY FOR FLIGHT TESTING

Gao Weimou

Data processing technique plays an important role in flight test of new aircraft. In this article, the basic features of data processing technique are briefly discussed, followed with its current development status. Special emphasis is given on the flight test data acquisition and processing systems used by the Center -- French made Damien system, "Lisan" system and "Qinchuan" system. Some work in associated software field is also mentioned [English abstract].

In the preparatory stages for flight testing, the testing process, and the reporting of conclusions, data processing provides extremely important support. With numbers, graphs, figures and control program codes, it offers outlines of data and code for use in testing, describes and displays the test process, judges the success or failure of the test, and provides conclusions on the performance and quality of target aircraft and equipment. For this reason, the development of test flight data processing technology has a close connection with the development of test equipment and computer technology.

### THE BASIC CHARACTERISTICS OF TEST FLIGHT DATA PROCESSING

Test flight data processing uses as its data source the data flow collected during test flight experimentation, or the data flow reproduced on a magnetic recording device. It has a strong real-time character. The amount of data is in direct proportion to the sampling rate. The computer in use needs special input channels, a large memory, and a high processing speed and response capability. The results of processing must have a high degree of authority, must be suitable for use in evaluation, and must be protected from divulgence. Our computers can satisfy all these requirements. They are equipped with a variety of high-quality foreign equipment and are completely outfitted with regard to hardware and software, as well as measurement systems.

### CURRENT STATE OF TEST FLIGHT DATA PROCESSING

The main systems currently in use in the Test Flight Center include the Damien system, the Lishan [transliteration] system, and the Qinchuan [transliteration] system. Each of them is equipped with a data processing system. The data processed on them comes from sampling devices, telemetric receivers and magnetic recording devices. There are two chief types of test flight data, PCM data and FM data, and real-time and after-the-

event processing methods are available.

The Damien system, imported in 1978 from SFIM of France, is equipped with the MITRA and multiple-use mini-computer system manufactured by SENS of France, used for preliminary system processing and final processing for small tasks. In the preliminary processing it is capable of receiving a PCM data-flow input at a sampling rate of 2 kbps and simultaneously processing 30-40 parameters. It uses the five-section



Technical personnel using a data processing system.

six-point two-point linear imaging method to implement parameter decoding checking. Preliminary processing preparation and preliminary processing are convenient and easy to control. The system does not feature real-time processing. Preliminary processing is a very important measure for determining the testing sequence.

In 1982, another testing system, the Lishan system, was installed. This is a magnetic/telemetric composite system consisting of a PCM real-time processing system and a PCM or FM oscillation analysis system. The PCM real-time processing system has a MITRA 125 multiple-use minicomputer system which can receive data flow input at a maximum rate of 16 kbps. It is able simultaneously to process about 100 parameters. The PCM or FM oscillation analysis system has a PRIN80 signal analysis computer system, also known as a PS system. The system has a great quantity of specialized software and is used chiefly for processing and analyzing oscillation data produced by the on-board measurement equipment of the Lishan computer. In the process of real-time analysis, a maximum parameter sampling rate of 1024 bits per second can be achieved from the PCM flow, and eight channels of oscillation data can be collected from the FM flow. The total FM sampling rate cannot exceed 100 kbps. Concerning FM signals, real-time display is possible for a maximum of four channels and real-time processing is possible for four channels. The structure of the Lishan system is complex, and it has a full range of functions.

The Qinchuan system installed in 1985 is a testing system for an electronic experimental plane. The collecting equipment of this system (RMDU) was previously used widely in American aviation and aerospace equipment. The system's data processing is divided into two parts, the on-board real-time processing component and

the surface after-the-event processing component. Real-time processing is performed by the VAX-II/730 minicomputer from DEC of the United States, with preliminary surface processing being carried out by the VAX-II/730. On the two computers is special software including an upward/downward compatible VAX/VSM operating system, a FORTRAN77 equivalent compiling language and a flight test data analysis system (FTDAS). The Qinchuan system only collects PCM data; in real-time collection mode it can receive a PCM data flow at a maximum rate of 17.857 kbps, and surface preliminary processing can receive a PCM flow at a rate of 62.5 kbps. Real-time and preliminary processing can process a maximum of 50-100 parameters. Except for the periodic manual operation required by plan, the flight test preparatory work is almost all performed on the VAX-II/730 FTDAS. Operation under FTDAS is by means of menu and form; this is a simple but advanced operating method popular throughout the world.

#### DEVELOPMENT AND USE OF TEST FLIGHT DATA PROCESSING TECHNOLOGY

In the application of data processing technology and during its course of development, the Test Flight Center has, for example, undertaken the development of measurement systems and successfully performed research on computer methods, writing interface and parameter extraction programs linking the Damien, Lishan, Qinchuan and other systems. In connecting our test flight tasks, we have studied the Newton-Laibusen [transliteration] method and have made important progress in parameter recognition in test flight data processing which we have applied widely in our work. We are currently continuing to enlarge our research and its application in this area.

From this, it can be seen that the Test Flight Center's real-time and accurate time data processing have approached or achieved the international standards of the 80s. In the area of final processing, because of the lack of large-capacity central computers, the data processing cycle is still relatively long. Because of this, simultaneously with designing and outfitting large-scale computers, it is necessary to emphasize work in the area of software. We must move our efforts in test flight data processing software in the direction of programmization, standardization, serialization, and production. This will speed up the development of final data-processing technology.

## MOVING PHOTOGRAMMETRY AND ITS APPLICATION

Sun Shunchang

The applications of moving photogrammetry in flight testing and photographic methods are presented. The status is presented [English abstract].

Moving photogrammetry is an important means for measuring external parameters in flight testing research. It uses a variety of high-speed photographic equipment to obtain a continuous moving image of a moving target, thus recording many dynamic-state parameters from the test target. In aerial flight tests, there are two categories of applications of moving photogrammetry: 1) Recording and analyzing high-speed experimental processes such as the movement from the plane of suspended external objects, weapon firing and the dispersion of exhaust, normative recording of cabin instruments, the path of ejection seats, etc. 2) Measuring moving parameters such as aircraft takeoff and landing data, the position in space of flying objects during tests (trajectories, speed, acceleration, elevation, and other data), the path of released objects, and bearing measurement.

The methods of moving photogrammetry differ according to the requirements of the task:

1. Timing information is provided on the basis of the frequency of photographs and the number of frames.
2. Regarding the measurement of spatial position of moving objects, it is possible to provide moving parameters for the absolute and relative coordinates of the test object. There are three methods of measurement: 1) Delayed photogrammetry; 2) tracking photogrammetry, which can be divided into fixed-point absolute coordinate tracking photogrammetry and moving-point relative coordinate tracking photogrammetry. Fixed-point photogrammetry uses a single station or multiple station tracking photogrammetric equipment (electronic photographic transits) to perform continuous tracking photography of the test object. Moving-point photography normally is performed using two or more airborne aircraft flying in fixed formation with photographers in these planes independently tracking and photographing the test object on the experimental plane. These include the ejection test vehicle ejection seat, externally mounted weapons on planes, and suspended objects that have been released.
3. State analysis and attitude measurement. Moving photogrammetry can be used to undertake analysis of experimental states and measurements of the attitudes of moving objects.



The Test Flight Center has specialties in high-speed photography and measurement, aviation remote sensing and photography, radar measurement, image analysis and data processing, special infrared target measurement, etc. It has a variety of advanced equipment including on-board high-speed cameras and automatic development and printing equipment, automatic film reading devices, and optical measurement units. A total of over 600 tests have been performed. Furthermore, technical tasks have been carried out including studies of physical exercise, fixed-direction explosion mining, aviation remote sensing, and hydroelectric station spillway monitoring.

# REMOTE SENSING FOR AERIAL PHOTOGRAPHY

Xu Jing Liang

The achievements of using PICS in aerial photography are presented. Side lapping can be reduced by 7%, so flight operation time can be saved by 10% [English abstract].

The special field of aerial photography (remote sensing) at the Flight Test Center has made great advances in recent years. In the area of equipment, there are special airplanes used in aerial photography with very advanced photographic installations. A comprehensive photographic control system (PICS) has been imported from abroad, and the methods for using it have been thoroughly mastered. We have achieved highly efficient, high-quality aerial photography (remote sensing), making our contribution to flight testing and the national economy. The PICS system is composed of an LTN inertial guidance system (including a remote control unit, or RCU), an aerial photographic device, and interface equipment. The system is installed in an airplane and linked with the automatic pilot; it can perform aircraft attitude measurement, aerial photography, and remote sensing measurement. The PICS system can be used in automatic air-to-surface grid photographs (see fig. 1). Automation includes alignment of the measurement line, opening the camera, automatic overlap, closing the camera, automatic turning, adjusting the camera's lateral drift and leveling it, interrupting and continuing the flight, and automatic jumpers. Automation improves flight quality, reduces the amount of required labor, improves efficiency and economic benefits, and produces excellent results. In areas that lack an obvious ground grid, automation's superiority is even more striking. Several years of experience at CFTRC have given us a mastery of the use of the PICS system. Currently, at an altitude of 10,000 meters over flatlands, we are able to maintain the plane's

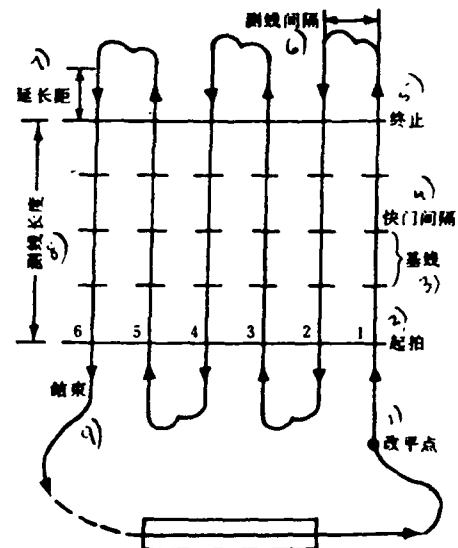


Fig. 1. Automatic grid photography. Key: 1) Leveling off point; 2) Begin shooting; 3) Base line; 4) Shutter interval; 5) End point; 6) Measurement line interval; 7) Extension distance; 8) Length of measurement line; 9) Conclusion.

deviation from the measurement line within 400 meters; over mountainous terrain, deviation is held to 600 meters; in desert, it is held to 800 meters. As the flight altitude decreases, precision can be further increased. The above-described precision can be maintained with an aerial photographic scale of 1:60,000; the side lapping averages 23%, with the minimum value still within the specified requirements for aerial photography.

China's "Aviation Photography Specification" prescribes a side lapping of 30%, with a minimum of no less than 15%; otherwise, supplemental flights are necessary. If the PICS system is used, supplemental flights can be greatly reduced. Furthermore, it has been demonstrated that the prescribed 30% overlap can be reduced an additional 7%; in other words, the most economic overlap is 23%. Reducing the overlap 7% means that the measurement line interval can be increased 10%; this is equivalent to reducing the measurement line, and consequently the flying time, by 10%.

The Test Flight Center's use of the PICS system has made aerial quality self-monitoring possible; this means that it is possible to inspect, while airborne, the flight path, spot the flight path, determine the amount of deviation, determine whether it is excessive, and perform supplemental flights in a timely manner, thus avoiding the necessity of waiting for a study of the photographs. PICS has effectively ensured quality, improved production efficiency, and saved manpower, equipment and material.

In 1980, during the course of one project, the PICS system was used to complete color and infrared photography for a large area at high altitudes. Remote sensing specialists have used color and infrared aerial plates in the area of imaged cartography, environmental geology, agriculture, forestry, water conservancy, ecology, city planning, and construction; it has been successful in 40 scientific projects. PICS has won a national scientific progress award.

In 1986, in the area of aerial photography, measures were again taken to change the measurement line intervals of the grids and the flight altitude, in order to increase the length of the measurement line and to shorten the turning time. This meant an additional, readily apparent improvement in production efficiency.

FEILUNDI [transliteration] PRODUCES AN  
OPTICAL COMMUNICATIONS INSTALLATION FOR HELICOPTERS

No Name

The Feilundi Company has recently come out with an on-board optical communications system able to make good the shortcomings of battlefield radio communications. This short-distance communications installation includes anti-interference and anti-interception features.

The installation uses a gallium arsenide laser diode and has an omnibearing distance of 500 meters. It is capable of receiving digital voice or data communication at a rate of 164 bps. Its power output is low; at a distance of 10 cm from the transmitting device, it presents no danger to the eye.

The installation consists of four sounding devices, one electronic installation, and an optional control board. By arranging the four transmitting and receiving units at angles of 90°, 360° coverage is obtained. The transmitters are positioned above the receivers. In each unit the transmitter includes two laser diodes, each covering a 45° field with a  $\pm 12^\circ$  vertical range. The receivers are four optical diodes, each with a 22.5° field and a  $\pm 12^\circ$  vertical range.

Under static conditions, the 16 receiving channels are all active. When they receive signals from the transmitters, only the directly opposed receiver and transmitter pair continues to maintain its active state. This makes it possible to ensure the transmitter's lowest radiation power, thus maintaining system secrecy, and reduces interference coming from the channels of the other 15 receivers. The channels on either side of the active channels are also scanned continuously. For this reason, if the movement of the airplane causes the signal position to shift, it is possible at any time to select a channel having the strongest signal. The cost for the entire installation is about the same as for a VHF/UHF radio installation.

## FLIGHT TESTING AIRCRAFT FIRE CONTROL, SPECIAL EQUIPMENT AND ELECTRONIC AND AUTOMATIC CONTROL SYSTEMS

Sun Sanceng

Past experiences, present status and future intentions on this topic are presented [English abstract].

The Test Flight Center's test flight research on fire control, special equipment, and electronic and automatic control systems includes five special fields: Electrical systems; gyroscopes, inertial guidance and atmospheric data computers; automatic aircraft control systems; fire control systems; and military equipment systems. Over the past 30 years, the electronic systems and course/attitude/atmosphere data computers and inertial guidance systems for 21 types of aircraft have been put through test flights, as have the automatic pilots of 11 kinds of aircraft with a variety of equipment, seven kinds of on-board fire control systems, many kinds of aviation weapons systems, and combined automatic flight guidance/pilot/bombing systems.

We have used electrical system flight testing technology, the flight test method of photographic analysis to measure aircraft bearing angles, and the normal variation method in flight testing combined aircraft and automatic pilot systems; and have performed research on flight quality of automatically equipped planes and on test flight methods for flight control systems. We have found solutions to a number of key technological problems and promoted the development of these special test flight techniques.

Flight testing has had an important effect on the development of this kind of on-board equipment. For example, some automatic pilots developed emanative vibration during test flights, or the hardware broke down causing violent movement in the plane's longitudinal direction, with an overload of 7; other problems not yet understood also occurred. In addition, on a number of temperature measurement test flights for weaponry, the data measured for the maximum temperature often exceed the limiting value of the design, sometimes, exceeding twice the limiting value; this is because of aerodynamic heating during flight. Heat dispersion conditions are quite complex, and difficult to predict during the design stage. These problems were finally solved, after flight testing and analytic research.

Recently, the Test Flight Center has used sophisticated real-time measurement and processing systems for flight test data in these areas, strengthening its test flight capabilities and improving test flight quality. It has actively engaged in research in new test flight technology such as parameter recognition and dynamic flight.

In the future, as China's horizontal display systems, digital automatic pilot, and other advanced equipment are successfully developed without foreign assistance, as automatic landing systems and active control technology are used successfully on aircraft, and as sophisticated test flight measurement equipment and technology are applied, the role of the Test Flight Center's test flights for on-board electronic equipment and fire control systems will be even greater, and the quantity of our work will increase day by day.

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